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THE JOURNAL OF THE RUBBER RESEARCH INSTITUTE OF MALAYA

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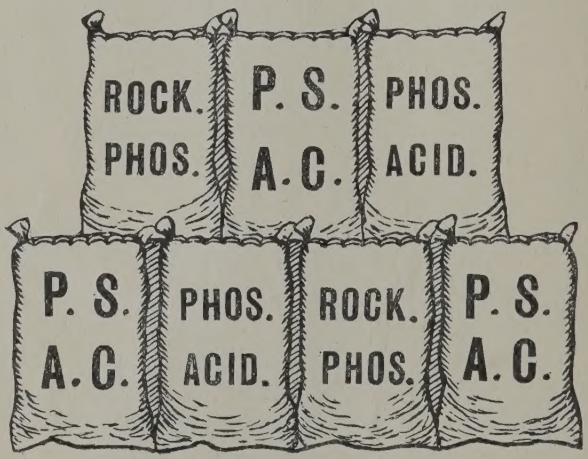

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THE

JOURNAL

OF

THE RUBBER RESEARCH INSTITUTE OF MALAYA

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THE RUBBER RESEARCH INSTITUTE OF MALAYA

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THE

JOURNAL

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THE RUBBER RESEARCH INSTITUTE OF MALAYA

VOL. 9 NO. 1 JULY, 1939 NO. 25 OF THE SERIES

EDITORIAL

This issue of the Journal contains papers on biological subjects and will be followed shortly by a further issue containing papers relating to chemical investigations. An apology is made for the

Correction

to the

Journal, Vol. 8, No. 3, November, 1938

On the front cover and on page 223 the *Journal* is numbered Vol. 8, No. 3 (No. 23 in the Series); the serial number should be **24.**

of magnesia (MgO).

This analysis reveals in striking fashion the large quantities of nutrient elements held in the tree, which may be lost if timber is removed from the land as for example during replanting operations. Burning will release the mineral elements so that they are returned to the soil in the ash without serious loss, but very heavy losses of nitrogen will occur as a result of complete burning. For example, burning the above-ground portions of old trees on an area under preparation for replanting on a basis of 80 trees per acre, may result in a loss of nitrogen equivalent to about six tons of sulphate of ammonia per acre. Decay of timber on the surface will also result in heavy losses of nitrogen but it may be interesting to investigate the relative amounts of nitrogen lost by the rapid destruction of timber by burning and slow decay under different systems of cultivation. Analyses of

the leaves and leaf-stalks show that on an acre-basis large amounts of the principal nutrient elements nitrogen, phosphoric acid, potash, lime and magnesia may be regularly lost to the tree during leaf fall. Dr. Dyck draws attention to the importance of further study of the nitrogen status of the leaves at different seasons.

Chemical Composition of Rubber Trees in relation to Nutrition and Manuring

Commenting upon the results presented by Dr. Dyck, the Director draws attention to the importance of the data obtained from the analyses of the foliage, leaves and leaf stalks, in its bearing on problems of nutrition and manuring of the rubber tree.

It is shown that on an acre-basis the amounts of the more important nutrient elements lost to the trees in an annual leaf-fall are equivalent, in terms of the common fertilisers, to about one ton of sulphate of ammonia, two hundredweights of rock phosphate and 3½ hundredweights of sulphate of potash per acre. The importance of ensuring that losses from this cause may be reduced to a minimum by correct cultural practices is stressed. At the same time, it is emphasised that whilst losses of mineral nutrients may be reduced to negligible amounts, considerable losses of nitrogen are bound to occur in the course of decay of the leaf residues on the soil surface. The annual losses of nitrogen which occur as a normal consequence of the deciduous habit may be quite sufficient to account for the important role which nitrogen has been shown to assume in all investigations on the nutrition of the rubber tree. The need for further investigation of this important aspect of work on the nutrition of the rubber tree is emphasised; further analyses will be made on trees growing under different environmental conditions.

Plant Hormones

In the course of investigations on vegetative propagation of Hevea, Dr. E. D. C. Baptist has carried out a number of preliminary tests with a wide range of chemical growth stimulants. This work has developed from attempts to obtain, by vegetative means, stocks for budding which will be uniform in their characters. The use of uniform stocks for budding may help to reduce the variation in growth and yield of budded trees.

During recent years notable advances in the technique of propagation have been made by the use of plant hormones or growth-stimulating substances and a general review of the more important work is presented in this paper. The results reported for Hevea show that rooting of cuttings made from the lower

sections of the stems of Hevea seedlings may be stimulated to a marked degree by appropriate treatment with certain growth substances. Rooting of cuttings made from young scions or from the branches of budded trees has not yet been obtained by any of the stimulants used.

Experiments on the rate of regeneration of roots on seedling and budded stumps have shown marked responses to treatment with growth substances. The use of solutions of suitable hormone substances may prove of considerable practical value in the planting of budded stumps. Acceleration of rooting has been shown to reduce greatly the proportion of losses on transplanting, a factor which has been mainly responsible for the preference in Malaya for budding in the field to planting with budded stumps. Practical instructions for the treatment of budded stumps with various proprietary preparations of plant hormones have been issued. (*R.R.I. Planters' Bulletin* No. 4).

The effect of plant hormones in stimulating the rate of bark renewal after tapping is also under investigation and further reference to this aspect of the work is made in the paper by Mr. Beeley and Dr. Baptist.

Palm Oil as a Diluent for Fungicidal Oils and its Effects on Bark Renewal

In connexion with his investigations on the control of fungus diseases of the tapping panel Mr. Beeley has previously recorded that certain vegetable oils, notably linseed oil, used as vehicles for fungicides appeared to have a stimulating effect on the rate of bark renewal on treated trees. In the course of further tests of the fungicidal value of tar oil preparations an opportunity to investigate the use of a vegetable oil as a diluent for the fungicides arose. In view of the possible connexion between growth stimulation and the presence of plant hormones in physiological concentrations in certain vegetable oils, collaboration with Dr. E. D. C. Baptist was arranged.

The results of the tests showed that palm oil is a satisfactory diluent for tar oil fungicides. Effective control of the Mouldy Rot fungus was obtained by treatment of the tapping panels at weekly intervals with palm oil-fungicide mixtures containing five to ten per cent of tar oil. Repeated treatment of the same surface resulted in penetration and killing of the outer layers of bark but single treatments of the freshly exposed tapped surface at weekly intervals did not result in such damage.

Stimulation of the rate of bark renewal by the palm oil dressing has been clearly demonstrated. The presence of the fungicidal oil has had no apparent influence on the effect of palm oil on bark renewal and in all treatments where palm oil was used

increases in bark thickness of from 25 to 50 per cent over the controls is recorded. This improvement may be due to the presence of a growth-stimulating substance in the palm oil or to the protection afforded by the oil film in reducing evaporation from the young tissues near the renewing surface. It seems probable that both factors are of importance and further study of the influence of vegetable oils on the rate of bark renewal on trees of different ages under different conditions is desirable.

A Nematode Pest of Roots of Cover Plants

The presence of an eelworm pest in the roots of cover plants commonly used on estates has been known for some time but only recently has it been realised that this pest may be the cause of failure of leguminous plants on many of the alluvial soils of Malaya. In this paper Mr. Beeley describes the pest and its mode of attack on the roots, so that the symptoms may be more easily recognised by estate managers and the root galls differentiated from the true nodules of the nitrogen-fixing bacteria. He also discusses the precautions to be taken to prevent infestation of the soil and measures which may be adopted in an infestation already present.

Oidium Heveae in 1939

Mr. Beeley's observations on the incidence of mildew (*Oidium Heveae*) during the current year lend further support to the view previously expressed that, in general, conditions in Malaya do not favour the rapid development of this disease. On the whole, climatic conditions during the latter half of 1938 and during early 1939 were inimical to the development of Oidium. In the North, early defoliation occurred and refoliation was almost complete before the dull weather and light rains of February and March created the conditions favourable for mildew development. In the Central and Southern districts "wintering" was delayed by the January rain after a very dry monsoon season, and mild attacks of Oidium were observed. It is feared that blossom infection in some districts may have been heavy and that seed crop will be poor in consequence.

Interesting observations on the early appearance of the fungus were made which strongly support the view that the spores of the fungus are carried over from season to season in the buds.

General Recommendations for the Development of Jungle Reserve Land for planting with Rubber Trees

In accordance with custom the texts of papers presented at the last Annual Conference of the Incorporated Society of Planters

are reprinted in the *Journal*. Papers by the Director and by Mr. C. G. Akhurst on the preparation and early cultivation of new areas, and the paper by Mr. C. E. T. Mann on choice of planting material are reprinted. The paper by Mr. N. Wright on yields of budded areas in commercial practice has not been reprinted, as considerable additions have been made to the data available at the time the paper was prepared and an account of these will be published shortly.

R.R.I. Planters' Conference

It is regretted that it has not been found possible to republish the papers presented at the R.R.I. Conference in July 1938 on the Role of Cover Plants in Rubber Cultivation. Advance proofs of the papers read at this Conference were published in a supplement to *The Planter* (Vol. XIX No. 6, June 1938), and in the digests distributed at the Conference, but it was intended to republish these, with accounts of the discussions, for the information of those who were unable to attend the Conference. Owing to the early departure of the Director on leave and his absence during the first half of the current year the publication of the full proceedings of the Conference has been unavoidably delayed.

Kuala Lumpur,

3rd July, 1939

THE AMOUNTS AND DISTRIBUTION OF SOME OF THE NUTRIENT ELEMENTS IN THE RUBBER TREE

BY

A. W. J. Dyck

Introduction

In the study of plant nutrition great importance is attached to the relative amounts of the different elements in the soil and the soil-solution, their rate of absorption by the roots, and their translocation within the plant.

It has, for instance, been found that the translocation of a certain ion within the plant may either be hindered or accelerated by the presence of another ion. Thus, broadly speaking, the nitrate ion and, to a less extent, the potassium ion accelerate the transportation of the other elements into the leaves. The marked improvement of the foliage of trees following manurial applications of ammonium sulphate or sodium nitrate is common knowledge. What is not so commonly understood is that nitrogenous manures, acting largely as promoters of this effect, are only partly responsible and that it requires the aid of the rest of the essential elements to bring about this improvement of the foliage. The relative concentration of the various elements in the soil solution may influence the rate at which an ion is absorbed by the roots. The presence of one element in excess may seriously interfere with the normal absorption processes of another element, even though in a better balanced soil solution the same amount of the latter would have been adequate to ensure good growth of the plant.

It might not be far wrong to assume that there are relatively few elements which remain entirely neutral and exhibit no antagonistic or accelerating effects in any of the processes connected with absorption or translocation of the ions.

A knowledge of the composition of any particular soil does not necessarily give an accurate indication of the actual value of that soil for agricultural purposes. On the basis of results obtained from chemical analysis a soil may be adequately supplied with nutrients and yet growth of the plants may proceed unsatisfactorily.

These are difficulties the investigator has to contend with in dealing with so complex a mixture as the soil, in which chemical, physical, and biological properties combine to make the problems even more difficult.

To get a clearer picture of the problems of plant nutrition it is essential to co-ordinate the results obtained from soil and plant analyses and to interpret them in the light of physical, chemical, and biological processes taking place in both the soil solution and the plant. To attempt a satisfactory solution of problems of plant nutrition on the basis of growth and yield measurements alone, as is sometimes the practice when field manuring experiments are carried out, often leads to discouraging results. The fertiliser mixture which produces maximum growth in one field may not necessarily produce similar effects on the same soil type in another field. Again, the effects produced by the same mixtures can frequently not be duplicated in the same field from one year to another. It cannot be over-emphasized that the soil is not a static but a dynamic system.

Similarly, an interpretation of the nutrient requirements of the plants on the basis of results obtained from chemical analyses of the soils and the plants often leads to erroneous conclusions because the processes and mechanisms of absorption and translocation of the elements are either ignored or not fully understood. What is essential is some understanding of the influence one element exerts on the other in the course of these processes. With the aid of such knowledge the composition of the soil solution and the concentration and distribution of the nutrient elements in the plants will acquire a new meaning, and the soils investigator will be in a better position to ascertain the fertilizer requirements of any growing plant under any conditions.

We have little knowledge of the nature of these processes taking place in Hevea trees. Problems of this nature are now being investigated by various workers with other plants. The results achieved along these lines show, as already mentioned, evidence of the antagonistic and beneficial effects the elements exert on one another during the process of absorption and translocation and the fact that a differently balanced nutrient solution is required by each individual plant-species to produce maximum growth. In other words the optimum ratio $\frac{\text{the elements within the plants}}{\text{the elements in the soil solution}}$ is a different one for each plant species.

It is partly from the point of view of these absorption and translocation processes of the ions in the plants that the results summarized in Tables I and II are discussed. The fact that the evidence obtained from the analysis of a single rubber tree contributes but little towards a knowledge of these processes is fully understood. The object of this paper is merely to sum

up the problems that confront the soils investigator in this field and to initiate a much desired angle of approach.

Description of the Tree and the Preparation of Samples for Analysis

A tree, about 60 feet high and 29 inches in diameter at ground level, growing on Wardieburn Estate on a soil derived partly from limestone and calcareous rocks and partly from quartzite was selected for this study. The foliage was of a healthy colour and no signs of deterioration of the tree or of nutrient deficiencies were apparent.

The tree was felled towards the end of November, 1938, and separated into the various fractions shown in the Tables. The fractions were weighed (the total tree weighing 11,700 lb.) and representative samples of each were taken. In the case of roots, stems, bark, and branches cross sectional shavings were taken for analysis.

Results and Discussion

The results of analysis are summarized in Tables I and II.

(a) The Distribution of Nutrient Elements in the Tree

Plant nutrients, once absorbed by the roots, are transported through the xylem to the leaves and then through the phloem to the bark and stem. In the case of monovalent ions such as Na^{+}, K^{+}, which are more mobile, it has been found that they are transported through the tree at a higher rate than the divalent ions and are to a large extent deposited in the bark and in the stem. The content of the monovalent ions in the bark and in the stem is reported to be normally quite high. On the other hand, the less mobile divalent ions such as Ca^{++}, Mn^{++}, Mg^{++}, it is reported, are to a large extent retained in the roots of the plants, particularly in the case of Ca and Mn. Smaller amounts are translocated to the leaves and still smaller quantities to the stem.

How then do the results in Table I agree with this distribution of elements which according to some workers holds generally for all plants?

In the case of potassium the agreement is far from good. We would expect a high potash content in the stems and in the bark and a low potash content in the leaves. Actually we find a high potassium content in the leaves, leaf stalks, and twigs, and a low potash content in the wood of the stem. There is, however, a high concentration of potassium in the bark. In the case of sodium the results appear to be in better agreement with the above postulates, except that the concentration of this element in the roots is higher than might be expected. The sodium con

TABLE I

Analysis of a Rubber Tree

(All values with the exception of Moisture are expressed as percentage of oven-dry weight)

Fractions	Total Moisture	Ash	Nitrogen N	Phosphate P_2O_5	Potassium K_2O	Calcium CaO	Magnesium MgO	Sodium Na_2O	Manganese MnO_2
Leaves ...	59.65	6.28	2.67	.37	1.14	2.00	.78	.001	.038
Leaf-stalks ...	65.60	5.42	1.23	.23	1.33	1.76	.29	.017	.042
Twigs ...	64.50	6.47	1.14	.35	1.46	2.19	.17	.085	.041
Small branches ...	43.64	2.46	.41	.13	.44	.96	.10	.011	.018
Side branches ...	26.50	2.17	.40	.14	.50	.77	.10	.006	.016
Main branches ...	22.15	1.89	.33	.10	.36	.76	.10	.008	.022
Bark ...	52.76	8.01	.42	.12	1.15	3.38	.11	.018	.039
Upper stem ...	29.44	2.08	.31	.12	.43	.48	.24	.017	.015
Lower stem ...	34.40	1.23	.34	.10	.44	.33	.30	.014	.014
Tap root ...	31.73	2.25	.40	.15	.56	.56	.21	.011	.023
Lateral roots ...	47.49	4.20	.57	.23	.67	.92	.27	.046	.025
Small roots ...	—	3.76	.75	.26	.69	.85	.32	.083	.029

TABLE II

Composition of a Rubber Tree

weighing 11,700 lb.

Values Expressed in lb.

Fractions	Total Weight	Moisture	Dry Weight	Organic Matter	Ash	N	P_2O_5	K_2O	CaO	MgO	Na_2O	MnO_2
Leaves ...	367.0	219	148.0	138.71	9.29	3.95	0.55	1.68	2.96	1.14	0.0015	0.056
Leaf-stalks ...	56.0	37	19.0	17.97	1.03	0.24	0.04	0.25	0.33	0.05	0.003	0.008
Twigs ...	650.0	419	231.0	216.05	14.95	2.63	0.81	3.37	5.06	0.40	0.196	0.094
Small branches ...	637.0	278	359.0	350.17	8.83	1.58	0.46	1.58	3.45	0.36	0.039	0.064
Side branches ...	1230.0	326	904.0	884.4	19.60	3.71	1.26	4.52	6.96	0.90	0.054	0.144
Main branches ...	3657.0	885	2772.0	2719.6	52.40	9.14	2.77	9.97	21.06	2.77	0.221	0.609
Main stem ...	3338.0	1065	2273.0	2235.5	37.50	7.25	2.50	9.88	9.20	6.13	0.352	0.329
Roots ...	1764.0	559	1205.0	1165.6	39.40	5.78	2.37	7.43	8.73	2.94	0.346	0.181
Total ...	11699.0	3788	7911.0	7728.00	173.00	34.28	10.76	38.68	57.75	14.69	1.2125	1.495

tent in the stem and in the bark is roughly 16 times its concentration in the leaves. Unexpectedly high are the concentrations of this element in the twigs and to a smaller degree in the leaf-stalks, which contain 85 and 17 times respectively the amount of sodium present in the leaves. Whether this somewhat abnormal distribution of sodium is caused by an actual deposit of this element in the twigs or whether the explanation should be sought in the low mobility of the highly hydrated sodium ion through the phloem it is impossible to state. The distribution of the sodium in the roots, decreasing in the order of small roots, main lateral roots, and tap root, suggests a comparatively low rate of translocation possibly for this reason.

In the case of the divalent elements the concentration of calcium in the roots is roughly twice its concentration in the stem, while the leaves, leaf-stalks and twigs contain about five times as much calcium. Similarly the magnesium content in the leaves is roughly three times that of the stem. An anomaly, however, exists here in so far as the concentration of magnesium in the roots is the same as that in the stem. The manganese distribution within the tree is similar to that of calcium. Its concentration in the roots is roughly twice the concentration in the stem, and the leaves contain nearly three times that amount. Striking are the extraordinarily high values for calcium and manganese in the bark.

Table II is of interest in so far as it shows the actual amounts, in pounds, of the various elements present in the tree, as a whole, and in its different parts. Noteworthy is the large amount of lime present in the tree. As can be seen from the Tables the lime-content is nearly double that of nitrogen. The amount of potash is equal to that of nitrogen, whereas the amount of phosphoric acid is less than one-third of the potash content and almost equal to that of magnesia. Whether this low phosphorus content is a result of the observed low available phosphate status of Malayan soils, or whether these relative figures are normal with rubber trees, only future investigations can show.

A previous analysis of the mineral constituents of an ash obtained from an eleven-years-old rubber tree was made by Bamber in 1916. Comparing Bamber's results with those presented in this paper

	Bamber's Results	Present Results
Lime	20.60 per cent	33.4 per cent
Magnesia ...	6.40 „	8.5 „
Potash	12.65 „	22.3 „
Soda	15.24 „	0.7 „
Phosphoric Acid ...	7.16 „	6.2 „

a striking discrepancy becomes apparent in the case of the sodium contents. Bamber reports 15.24 per cent soda against the present value of 0.7 per cent. It is very unusual for the sodium content to be higher than or even approach the potassium content in plants. It should be mentioned that the sodium determinations presented in the present paper were made by the zinc uranyl acetate method and should, therefore, be reasonably accurate. The 60 per cent higher lime-content as shown by the present results may be due to the fact that, as already mentioned, this tree was growing on a soil partly derived from limestone. Similarly, the difference in the potash contents could be ascribed to differences in available potash in the two soils.

Only qualified practical significance can at this point be attached to the results presented in this paper. Further extensive investigations will be necessary before conclusive interpretations can be deduced from data showing the distribution of elements in rubber trees. Similar investigations to those described above, including a spectrographic determination of minor elements, are at the present being carried out by the author on young rubber seedlings grown under different fertilizer treatments. Once the effects ions exert upon one another are fully understood a knowledge of the distribution of the elements in the trees will throw some interesting light on their manuring requirements, as it directly reflects any distorted balance of the nutrient elements in the soil solution.

(b) The Total Amounts of Nutrient Elements in the Tree

It is of interest to consider the amounts of nutrient elements present in the tree as a whole; and also, in relation to the leaf-fall, in the leaves and leaf-stalks; and to discuss these figures in the light of manuring problems of Hevea.

If the content of the minerals in the leaves remains unchanged when the leaves fall the annual amounts of plant nutrients returned to the soil in terms of this particular tree would be:

Nitrogen	... ...	4.20 lb.
Phosphoric acid	... ...	0.59 „
Potash	... ...	1.93 „
Calcium oxide	... ...	3.29 „
Magnesium oxide	... ...	1.19 „
Manganese dioxide	... ...	0.06 „
Sodium oxide	... ...	0.004 „

It is, however, very unlikely that these values represent the actual or even the approximate amounts which are lost by the

tree during the annual leaf-fall. It must be remembered that these values were obtained from the analysis of green leaves interrupted in their normal functions as a part of a growing tree. The composition of the leaves when discarded by the tree under natural conditions is, no doubt, different and it is likely that a drastic translocation of the minerals takes place from the leaves back into the tree just prior to shedding. In the case of nitrogen, however, this may not be so. Investigations are now in progress concerning the seasonal variation of the nutrient elements in the leaves.

Further consideration is given to this question, and to other aspects of the results in Table II, in the note by Page which follows this paper.

Summary

The distribution and the actual amounts of some of the nutrient elements in the Hevea tree are shown in Tables I and II. These results are discussed in the paper.

Acknowledgment

The author expresses his appreciation to Mr. K. S. Pillay under whose direct supervision the analyses were carried out.

Kuala Lumpur

1st May, 1939

THE CHEMICAL COMPOSITION OF RUBBER TREES, IN RELATION TO PROBLEMS OF NUTRITION AND MANURING

BY

H. J. Page

In the preceding paper Dyck has presented the results of the chemical analysis of a mature tree of *Hevea brasiliensis*, showing the distribution of the main nutrient elements derived from the soil, among the various parts of that tree.

Dyck's results for the content of nutrient elements in the leaves and leaf-stalks of the tree, if expressed on the acre-basis, assuming a stand of 100 trees per acre, are:—

Nitrogen (N)	420	lb.
Phosphoric acid (P_2O_5)	59	„
Potash (K_2O)	193	„
Calcium oxide (CaO)	329	„
Magnesium oxide (MgO)	119	„
Manganese dioxide (MnO_2) ...	6	„
Sodium oxide (Na_2O)	0.4	„

These represent surprisingly large amounts, especially if stated in terms of the weights of commercial fertilisers to which they correspond. For example, the amounts of nitrogen, phosphoric acid and potash correspond to the following dressings of fertilisers:— sulphate of ammonia, 19½ cwt.; rock phosphate, 1½—2 cwt.; sulphate of potash, 3½ cwt. Dyck has pointed out however, that the leaves, at the time of the annual leaf-fall, may contain much smaller amounts of mineral nutrients than they did in the fresh green condition in which they were collected for his analyses. It is doubtful, however, whether this applies equally to the nitrogen content of the leaves, which may be of the same order when they are shed, as it is when they are green.

The mineral nutrients are not subject to loss into the air in gaseous or volatile form, so that the actual amount of them in the leaf-fall is of secondary importance in its bearing on manuring problems. Provided that ground cover conditions are such that the leaf-fall is retained and not allowed to wash or blow away, the minerals in the leaf-fall will ultimately find their way back into the soil and thus complete without appreciable loss the cycle: absorption from soil by roots → translocation to leaves → fall of leaves to soil.

The position regarding nitrogen is, however, quite different. Even if the fallen leaves became immediately incorporated in the soil, some of their contained nitrogen would probably be lost either into the air or in drainage. Actually, however, most of the leaves decompose on or above the surface of the soil, not in it; under these conditions it is certain that, during their decomposition, much of the nitrogen contained in them will be dissipated into the air and so lost. If, as seems not unlikely, in contrast to what obtains for the mineral elements, much of the nitrogen present in the green leaves remains in the leaves when they are shed, it is clear that there would be a serious leak in the cycle of nitrogen from soil to tree and back. For example, if the leaf-fall contained the amount of nitrogen shown above, and if only one-fifth of this were lost into the air (and in drainage) at the annual leaf-fall, this would correspond to the amount of nitrogen in an annual dressing of about four cwt. of sulphate of ammonia per acre. It is known that the amount of nitrogen removed annually in latex, as a result of tapping, is relatively negligible; it is of no practical account in relation to the nitrogen economy of the mature Hevea tree. These results, however, show that the nitrogen losses associated with the annual leaf-fall, on the other hand, may be quite sufficient to account for the important part which nitrogen-supply has been found to play in the maintenance of healthy stands of Hevea. The further experimental study of this matter is of considerable practical importance in relation to the manuring of Hevea.

In spite of the facts that, in the case of the mineral cycle, there is no serious depletion as a result of removal of latex in tapping nor any reason to expect serious leakage as a result of the leaf-fall, the growth of rubber trees is nevertheless found to be accompanied by marked depletion of mineral element, notably phosphorus, from many Malayan soils. In this connection it is important to remember that, so long as the trees are standing, the soil has been deprived of the whole of the amount of mineral elements which are locked up in the tissues of the trees. Moreover, when these trees are felled, the manner of their disposal may have a marked influence on the mineral economy of the soil. If the burning or rotting of the trees is so managed that the minerals released in the form of ash or otherwise are evenly distributed and find their way back into the soil, the return to the soil of phosphoric acid, potash and lime would, on the basis of Dyck's analyses and assuming a stand of 100 trees per acre, be equivalent in value to about one ton rock phosphate, 3½ tons sulphate of potash and 4½ tons limestone. If, however, the ash is allowed to wash away, or is very unevenly distributed, or if the

timber is removed from the land, the loss to the soil may be serious. For example, on the above basis, if the stem and only the main branches are removed as timber, the loss would correspond to about one-half of the above amounts of rock phosphate, of sulphate of potash, and of limestone, *i.e.* ½ ton, 1¾ tons and 2¼ tons per acre respectively. Such factors must be included in any calculation of the economics of the sale of rubber timber as firewood off the estate. Of course, if it is used as fuel for the smoke-house, and if the smoke-house ash is suitably conserved and returned to the land, there will be little serious loss.

The nitrogen contained, per acre, in the tissues of the trees at a stand of 100 per acre, on the above basis, corresponds to that in no less than nearly eight tons of sulphate of ammonia. If the trees are burnt, either on or off the land, all this nitrogen is lost into the atmosphere. A substantial part of it is similarly lost even when the timber and debris are allowed to rot. It is not surprising, therefore, that nitrogen supply, by manuring or otherwise, is of paramount importance in the growth of the rubber tree, and that nitrogenous manuring, and the growth of leguminous covers, are vital factors in replanting programmes on most Malayan soils.

Since the above considerations are based on the analysis of only a single tree, too much weight must not be given to the actual amounts of nutrients, and of corresponding fertilisers, which have been cited. Further information is needed, from the analyses of other trees growing in other soils and situations. Notwithstanding this, it is reasonably certain that the variations in analysis that such further work will reveal, though they will probably be considerable, will not be so great as to invalidate the general conclusions here drawn, and that the amounts of nutrients and fertilisers involved will prove to be of the same order as those given in this note.

Harpenden

17th May, 1939

PLANT HORMONES

BY

E. D. C. Baptist

Introduction

The word hormone from a Greek word meaning to "arouse to activity," was first used in animal physiology by Bayliss and Starling (1) in 1906 and in plant physiology by Fitting (2) in 1910.

Hormones are chemical substances, quite distinct from nutritive materials. They are produced in certain cells or tissues and transferred to other tissues of the same organism where they determine and regulate physiological processes. Other names in common use for plant hormones are phytohormone, growth substance, growth-promoting substance, growth-regulator, "Wuchstoff" and auxin.

The investigations of Charles Darwin marked the beginning of research on plant hormones. Darwin(3) in 1880 showed that when young shoots of seedlings are illuminated from one side some influence perceived by the growing tip is transmitted downwards along the shaded side and the seedlings bend towards the light. It was not until 40 years later that Boysen Jensen (4) and Paal (5), showed conclusively that the influence or stimulus was of chemical nature and was caused by a growth-substance or growth hormone, formed and secreted at the growing point. The curvature observed in Darwin's experiment was caused by the increased growth of the shaded part of the young shoot due to the presence there of a higher concentration of growth hormone. The bending of horizontally-placed roots and shoots has also been shown to be caused by an unequal distribution, under the influence of gravity, of hormones on the two sides of the growing region of these organs (Cholodny (6)).

The famous German botanist Sachs (7) in 1882 postulated the existence of a special root-forming substance which is formed in the leaves and transmitted to the roots. He confirmed results, obtained by Duhamel du Monceau (8) in 1758, that, on a ring-barked stem, callus and, under favourable conditions, roots are formed above the rings where downward movement of the hormone is interrupted. Sachs explained morphological differences in plants as due to the influence of specific organ-forming substances.

Beijerinck (9) in 1888 ascribed the development of galls on leaves to a stimulating material, "growth enzyme," the action of which he likened to that of an enzyme in that it is effective

when present in minute amounts. We now know that cell outgrowths on leaves can be artificially produced by local applications of the synthetic auxin, indolyl-acetic acid (La Rue (10)). The initiation and growth of nodules on the roots of leguminous plants are, according to Thimann (11), caused by the auxin produced by the symbiotic bacteria. Errera (12) ascribed apical dominance and inhibition of lateral buds to an internal secretion by the apical bud of the main stem. Loeb (13) found that leafy shoots of Bryophyllum root more vigorously than defoliated shoots and suggested that root formation is stimulated by a hormone.

Van der Lek (14) showed that the presence of a young leaf or developing bud on a woody cutting promotes root formation. Similar results were obtained with Acalypha cuttings by F. W. Went (15) at Buitenzorg in 1929 indicating that root formation was due to hormones produced in leaves and developing buds; these hormones migrate and accumulate at the basal end of the cuttings. Further investigations by Bouillene and Went (16) showed that rooting could be stimulated on some defoliated and debudded cuttings (which form few or no roots) by grafting a leaf or by treating the apical end with a water extract of papaya leaves or with diastase. The first evidence was thus obtained that specific substances formed in the leaf could stimulate root growth.

Went named the active substance rhizocaline, the root-forming hormone, and by the development of a sensitive biological method, the Avena test, was able to determine its chemical nature. These growth substances are formed in young leaves growing in the light and disappear slowly when the plants are placed in the dark (Avery (17)). Older leaves produce little or no hormone (Thimann and Skoog (18)). Gregory (19) had postulated the existence of a substance necessary for leaf growth which is formed in leaves under the influence of light. Growth substances are also present in the seeds of plants and play an important part in germination and early growth of the seedling.

Seubert (20) was the first to show that growth substances occur outside the plant and to demonstrate their presence in human saliva, diastase, and malt extract. They are widely distributed in nature and have been found in rice polishings, in most vegetable oils, in peas, beans, lentils, tomatoes, oranges, and lemons, in foliage leaves and sprouting buds, in the pollen of many species of plants, in yeast, in some algae, in cultures of fungi or bacteria, in human saliva and in urine. Kögl, Haagen Smit, and Erxleben (21), (22) isolated in pure form three hormones or auxins. Two of these, auxin-a and auxin-b occur in the higher plants and the third, heteroauxin, is produced by fungi and bacteria. Heteroauxin when analysed was identified as indolyl-acetic acid,

a product of decomposition of protein, which had been isolated from human urine by Salkowski (23) in 1885 and prepared synthetically by Majima and Hoshino (24) in 1925. The root-forming properties of synthetic indolyl-acetic acid were first demonstrated by Thimann and Koepfli (25).

Zimmerman and Wilcoxon (26) of the Boyce Thompson Institute U.S.A. have shown that other organic acids, not known to occur in plants, also possess the property of stimulating root formation. They studied the effects of some thirty-two different compounds and found that alpha-naphthalene-acetic and indolyl-butyric acids were the most effective for root formation. Zimmerman, Crocker and Hitchcock (27) showed that ethylene, propylene acetylene and carbon monoxide induce root formation on the stems of many species of plants. The organic acids (synthetic auxins) are now available in pure form and their value for vegetative propagation has been tested at many centres. A number of growth substances placed on the market in England (six) and in the U.S.A. (twelve) and sold under various proprietary names are most probably solutions of indolyl-acetic acid, alpha-naphthalene acetic acid or indolyl-butyric acid or mixtures of these acids.

Other Factors affecting Rooting

Sugars are essential to the successful rooting of cuttings. Cuttings taken from plants grown in the dark and therefore depleted of carbohydrate reserves root feebly or not at all. Treatment with auxin solution to which sugar has been added may result in the formation of many times the number of roots formed as a result of treatment with auxin alone.

Biotin, a constituent of the yeast growth-promoting substance, bios, which was isolated in the crystalline state by Kögl and Tönnis (28) in 1936, has been shown by Went and Thimann (29) to cause a large increase in the number of roots formed on cuttings treated with auxin. Yeast extract has been shown by Robbins (30) and White (31) to be essential for the growth of isolated root tips in synthetic media. Kögl and Haagen Smit (32) obtained a large increase in growth of excised pea embryos in a medium containing only inorganic salts and sucrose by the addition of 0.00008 milligram of biotin per 10 c.c. of the culture solution.

Aneurin (vitamin B_1), the anti-beri-beri vitamin, is another factor necessary for root growth. Aneurin is formed in leaves in the presence of light and translocated to the roots. It is stored in seeds and is needed for the development of the seedling.

Went, Bonner, and Warner (33) showed that, on cuttings treated with auxin, the number of roots which grow out is limited

by the available aneurin. Leafy cuttings of Camellia, which had failed to root after repeated auxin treatment, were placed in a solution of aneurin (1 mg per litre) for 24 hours. One week later all the cuttings treated with aneurin had rooted successfully. Since aneurin without auxin treatment produced no rooting, proof was obtained that development of the embryonic roots (primordia) initiated in these cuttings by auxin is brought about by aneurin.

Ascorbic acid (vitamin C), which occurs in plants, was found effective in promoting profuse root and shoot development in willow cuttings at a dilution of 1 in 100,000 (Davies, Atkins and Hudson (34)).

The dividing line between a hormone and a vitamin is by no means well defined. A substance may be a vitamin to one organism and a hormone to another. Aneurin and ascorbic acid are true hormones for higher plants, but they are vitamins for most higher animals, which do not produce them.

Animal hormones.—A number of these hormones have been found in plants but their function in the plant is still obscure. Went and Thimann (35) have obtained evidence that a pure preparation of the female sex hormone theelin (oestrin) increases the number of roots developed by cuttings treated with auxin. Scharrer and Schrop (36) claim to have obtained increased production and growth in soya beans and other crops as a result of treatment with prescribed amounts of crystalline follicular hormones. Schoeller and Goebel (37) and Georgieff (38) obtained large increases in the weight of the fruit crop by dosing tomato plants with oestrone.

Root Formation on Cuttings

Tincker (39) has carried out extensive tests at the Royal Horticultural Society's Laboratories, Wisley, England, with a wide range of species of plants which are known to differ markedly in their ability to root from cuttings. He placed the plants into three groups (a) those rooting easily (b) those rooting less easily and (c) those rooting with great difficulty and found that 90 per cent of the species in group (a), 70 per cent of those in group (b) and 17 per cent of those in group (c) showed increased and accelerated rooting as a result of treatment with synthetic growth substances. Tincker obtained the best results with indolyl-acetic acid, indolyl-butyric acid and alpha-naphthalene-acetic acid which he found equally effective in causing increased rooting in about 54 per cent of the species tested. A number of proprietary solutions tested by him gave satisfactory results at the dilutions recommended by the makers. Several hundred plants were raised from the

FIG. 1. Treated basal cuttings from two-years-old seedlings showing profuse rooting six weeks after planting.

FIG. 2. Untreated basal cuttings from two-years-old seedlings showing callus but no roots six weeks after planting.

FIG. 3. Treated basal cuttings from two-years-old seedlings showing root formation five months after planting.

FIG. 4. Control basal cuttings from two-years-old seedlings five months after planting.

rooted cuttings and the initial advantage in growth due to accelerated and increased rooting was maintained in the subsequent growth of the treated cuttings.

Various methods of application of growth substance to plants have been tried: spraying, addition to the rooting medium, injection, local application in a lanolin paste (Laibach's method) but the best results have been obtained by standing cuttings in a very dilute solution of the growth substance in water for periods varying from 24 to 48 hours. Concentrations of one part in 10,000 to one in 20,000 have given good results for woody cuttings but the optimum strength of the solution varies with different species of plants. For herbaceous material a solution of one part in 40,000 has proved very effective. High concentrations damage the tissues.

Experiments with Hevea brasiliensis

(1) Cuttings from the Main Stem of Young Seedlings

Preliminary investigations carried out at this Institute on the effect of growth substances on the rooting of cuttings of Hevea have demonstrated a marked stimulation of root production.

Method of Treatment.—The basal ends of the cuttings are pared with a sharp knife and the latex allowed to exude. The coagulated latex is then peeled off and the cuttings treated by standing them with their bases in the solution of the growth substance for 24 hours. The basal end of each cutting is rinsed in water and the apical end dipped in just-melted grafting wax before planting.

Cuttings eighteen inches long from the basal part of the main stem of one and two-years-old seedlings all showed root formation within six weeks from planting after treatment for 24 hours with a proprietary growth substance at a dilution of 1 in 150 of water (1 fluid oz. per gallon). The treated cuttings had produced ten to sixteen roots each, the longest roots ranging from six to nine inches in length. (Plate 1, Fig. 1). The control cuttings which were stood in tap water for the same period of time before planting had formed a callus but no roots. (Plate 1, Fig. 2). Four months later the roots on the treated cuttings had attained a length of three feet (Plate 1, Fig. 3). One control cutting had produced one root six inches long in that time; others had formed a callus but no roots. (Plate 1, Fig. 4). The roots on the treated cuttings grew vertically downwards and had numerous lateral branches abundantly supplied with feeding roots which formed a dense network in the top foot of soil. The root distribution of one such cutting, thirteen months after planting in poor sandy soil, is well brought out in the drawing shown in Plate 2. The drawing was

made during the excavation of the rooted cutting and is an accurate representation of the roots in their natural position.

Subsequent investigations have shown that the position on the parent plant from which the cuttings are taken is an important factor for successful rooting. Four cuttings about fifteen inches long were made from the main stem of one and two-years-old seedlings at different times of the year and stood in weak solutions of each of several synthetic chemicals and of two proprietary growth stimulants for 24 hours before planting. The cuttings were labelled 1 to 4 according to their origin from the base of the stem upwards. Control cuttings were stood in tap water for the same length of time. Data from a large number of experiments are summarised below.

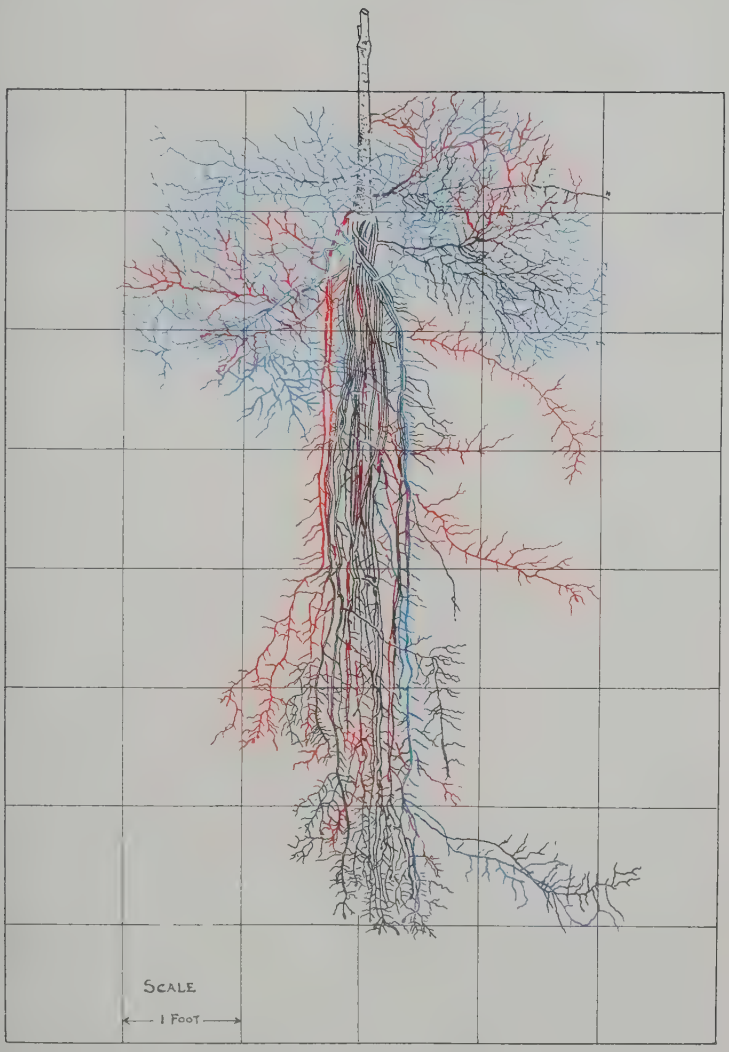
	Percentage of rooted Cuttings after three months	
	Treated	Control
Cutting No. 1 ...	90	19
„ No. 2 ...	28	3
„ No. 3 ...	8	<3
„ No. 4 ...	0	0

The basal cuttings from the main stems of young seedlings, which the preliminary experiments had shown to be relatively free rooting after treatment with growth substances, have been used in an investigation of some of the factors affecting rooting, such as the composition of the growth substance, the physiological condition of the cutting, the composition of the rooting medium, temperature and humidity.

Composition and Concentration of Growth Substance.—Cuttings removed in the late afternoon from the main stem of eighteen-months-old seedlings were treated with a number of different synthetic growth substances for 24 hours before planting.

The number of cuttings which formed roots is given below: the numbers in brackets refer to the number of roots produced on the successful cuttings upon examination eleven weeks after planting.

	Alpha-naphthalene-acetic acid		Indolyl-acetic acid	Proprietary Solution A	Tap Water
	0.03 g/litre	0.06 g/litre	0.03 g/litre	1 in 300	(Control)
Basal Cutting ...	3(28,8,5)	4(19,15,12,9)	2(5,4)	3(12,7,6)	1(6)
Cutting No. 2 ...	3(8,2,1)	2(1,1)	0	0	0



Basal cutting from one-year-old seedling showing root growth 13 months after planting. The roots shown in blue are to the front and those in red to the rear, of the central group of roots shown in black.

The results show that alpha-naphthalene-acetic acid at both concentrations used has been more effective in stimulating rooting than either indolyl-acetic acid or growth substance A.

The results of a comparative test of two proprietary preparations at different dilutions are presented below. The cuttings were lifted nine weeks after planting.

Treatment	No. of Cuttings	No. of Cuttings rooted	Roots		Shoots	
			Number	Wght. (gm)	Number	Wght (gm)
Growth substance A (1 in 640)	6	4	22+(14)=36	5.8	12	100.5
Growth substance A (1 in 320)	„	5	26+(14)=40	4.2	12	90.0
Growth substance B (1 in 900)	„	3	15+(8)=23	5.0	14	79.0
Growth substance B (1 in 450)	„	3	10+(4)=14	4.1	10	62.0
Growth substance B (1 in 230)	„	4	13+(16)=29	2.5	14	123.5
Growth substance B (1 in 115)	„	4	14+(10)=24	6.5	13	143.0
Tap Water	„	2	2+(5)= 7	0.5	10	62.5

The figures between brackets in column 4 refer to root swellings on the callus.

The percentage of rooted cuttings and the weight of roots produced have been increased by both growth substances at the concentrations used. The best rooting response, as judged by the percentage rooting and the number of roots produced, has been caused by growth substance A at both concentrations, while growth substance B at dilutions of 1 in 230 and 1 in 115 has produced the largest amount of shoot growth. The increased rooting obtained with substance A may have some bearing on the smaller amount of shoot growth as compared with the large increase in shoot growth obtained with substance B at the best concentrations.

Physiological Condition of Cuttings.—Cuttings from young seedlings taken at different times of the year, during the hot, dry season and during the wet months (September to November), have not shown any significant differences in rooting response. Preliminary experiments have given indications that the time of the day at which cuttings were taken from the plant might be an important factor in rooting response. Early tests indicated that cuttings made in the afternoon and treated with growth substance A showed

significantly better rooting than cuttings taken in the early morning. This is being further investigated.

Composition of the Rooting Medium.—Better callusing and rooting has been obtained in a medium of fairly coarse-grained sand than in fine river sand or coir dust or a mixture of sand and peat (2 of sand 1 of peat). Callused cuttings planted six to nine inches deep in the poorly aerated media of fine sand and coir dust showed blackening of the callus. Coir dust had a toxic effect on some cuttings.

Temperature and Humidity.—The saturated atmosphere and the smaller daily variation in temperature inside a Trinidad-type propagator had no marked beneficial effect on the rate of callusing and rooting of the leafless, hardwood cuttings used in these experiments. Equally good results have been obtained from cuttings planted in sheltered beds in the open, where the rooting medium consisted of a light sandy soil. The rate of opening of buds was, however, markedly accelerated in the case of cuttings planted in the propagator.

Cuttings used in these experiments were fifteen to eighteen inches in length with an oblique basal cut, not necessarily at a node. Shoot growth invariably preceded root growth; the bases of the cuttings had in most cases formed a thin complete ring of callus ten days after planting and buds began to break about ten days later. Roots usually made their appearance from six to eight weeks after planting but in a few isolated cases root initials have been observed as early as four weeks after treatment with growth substance. No root proliferation up the stem, as has been recorded for some other plants, has been observed with the concentrations of growth substance used and roots were always produced only from the wound callus. Cell outgrowths from the lenticels were almost invariably found near the basal end of the cuttings after a few days in the rooting medium.

(2) Cuttings from Budded Trees

Leafless hardwood cuttings from the main stem of one and two-years-old buddings and one to three-years-old branches of budded trees of various clones have shown no response to treatment with indolyl-acetic-acid and alpha-naphthalene-acetic acid at dilutions of 1 in 3,300, in 10,000, 1 in 25,000 and 1 in 33,300 of water and two proprietary growth substances at several concentrations. A very small number of cuttings developed a thin incomplete ring of callus but in no case was rooting induced. Shoot and leaf growth observed on many cuttings proceeded until the

food reserves became exhausted after which the shoots withered and died.

Attempts were made to induce rooting by increasing the carbohydrate reserves in the cuttings. The main stems of a number of two-years-old buddings were ringed a few inches above the union two months before severance so that the products of photosynthesis accumulated in the stem above the ring, as evidenced by the thick callus produced and the greatly increased starch content of the wood and bast cells. After severance, the stem was made into cuttings, fifteen inches long, which, after treatment with favourable concentrations of growth substance for 24 hours, were planted in a suitable sand medium contained in a propagator. Short leafy shoots were produced on a few cuttings but all cuttings had died without callusing six weeks after treatment.

Attempts to feed cuttings by placing their basal ends in solutions supplying nitrogen and sugars, were also made. The cuttings taken from branches of budded trees were treated for 24 hours with a favourable solution of growth substance to which had been added glucose 2 per cent, sucrose 2 per cent and urea 1 per cent, singly and in combination. Taka-diastase 0.01 per cent was also used as it was thought that the enzyme, by increasing the concentration of soluble sugars near the base of the cutting, might promote rooting. The results were negative, all the cuttings died without forming either root or callus about two months after planting.

In another experiment the cuttings were treated with several dilutions of two proprietary growth substances for 24 hours and planted in the propagator. Five days later half the number of cuttings in each treatment were taken out and the basal end placed in tap water containing one milligram aneurin (vitamin B_1) per litre for 24 hours after which they were returned to the rooting medium. Negative results were again obtained; all treated cuttings and the controls (treated with tap water) were dead three weeks after treatment.

Softwood, semi-hardwood, and hardwood cuttings taken from branches of budded trees during the early stages of refoliation after "wintering" (when the supply of food reserves and growth hormones are optimal) and treated with growth substance have also failed to show any sign of root development.

Treatment of ringed shoots with growth substance before severance for preparation of cuttings.

Main stems of vigorous young buddings two years of age were suitably ringed and the rings were treated with alpha-naphthalene-acetic acid dissolved in lanolin at concentrations of 1 in 100, 1 in 300 and 1 in 500. At the lowest concentration there

was a marked stimulation of callus growth; at the highest concentration callus growth appeared to be inhibited.

Six weeks after treatment the plants were cut down, cuttings were prepared from the ringed sections of the stem and planted in a propagator. The cuttings prepared from the ringed stems treated with the lowest concentration of growth substance and the cuttings treated with lanolin only showed healthy shoots at seven weeks from planting. The cuttings treated with the highest concentration of the growth substance died without shooting. None of the cuttings produced roots.

The failure to stimulate rooting in these experiments indicates that some factor or combination of factors, other than the presence of auxin, essential for the development of roots, is lacking in cuttings made from branches of Hevea or from scion shoots from plants propagated by bud-grafting. Repeated attempts with cuttings made from shoots of different ages with a wide range of concentrations of the more effective growth substances have met with no success in the stimulation of root growth from cuttings made from branches of buddings of Hevea.

Stimulation of Rooting on Transplanting

New root formation on an older root has been shown by several investigators (Bouillene and Went (16)) to be controlled by the same factors as root formation on a stem cutting. Zimmerman and Hitchcock (40) showed that growth substances also stimulate the formation of new roots on older roots.

These findings have been confirmed in experiments on the stimulation of rooting of Hevea "stumps." A number of eighteen-months-old seedling stumps were placed with the cut ends of the tap root in a solution of a proprietary growth substance in water at a dilution of 1 in 320 for 24 hours. Control stumps were stood in water for the same length of time. The stumps were planted in beds in the open and were carefully excavated after periods of one and two months and the results summarised below were recorded.

	One month after planting		Two months after planting	
	Treated	Control	Treated	Control
Total No. of Stumps ...	11	11	15	15
No. of rooted Stumps ...	7	3	15	10
Total No. of Roots ...	67	4	98	36
Fresh Weight of Roots (gm.)	—	—	90	30.5

FIG. 1. Seedling stumps treated with growth substance and dug up one month after planting. Root formation is accelerated and the number of roots formed is considerably increased, compared with untreated stumps of the same age shown in Fig. 2.

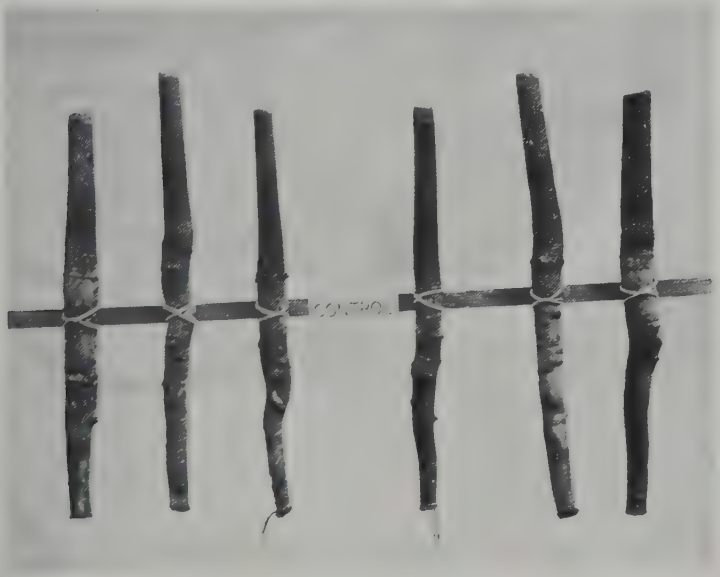


FIG. 2. Untreated stumps dug up one month after planting.

Budded stumps dug up three months after planting. The two stumps on the right were treated with growth substance; the two on the left were not treated.

The results show a marked acceleration in rooting and a large increase in the number and weight of roots formed as a result of treatment with the growth substance (Plate 3).

The stumps used for this experiment were trimmed shorter than would be the case in normal planting practice but this does not affect the results obtained.

Similar experiments were carried out with budded stumps with the results shown below.

Budded stumps planted in the field under favourable weather conditions.

	No. of Months after Planting					
	2 Months		4 Months		6 Months	
	Treated	Control	Treated	Control	Treated	Control
No. dead ...	0	6	2	8	3	8
No. with bud shot	58	46	69	63	69	63
No. alive, bud still dormant ...	14	20	1	1	0	1
Average height (inches) ...	14.6	12.8	18.2	14.2	25.0	22.7

A number of stumps in each treatment were excavated three months after planting and quantitative data of root and shoot growth are given below.

	Roots per Stump		Average weight of Shoot and Leaves in gm.
	Number	Weight in gm.	
Control	21	28.2	51.0
Treated	12	14.6	34.9

The results show that treatment with growth substance has accelerated both root and shoot growth and has reduced the number of losses on transplanting. (Plate 4).

Budded stumps planted in the field during a dry period

	Time after Planting			
	1 month		2 months	
	Treated	Control	Treated	Control
No. dead	1	3	3	36
No. with bud shot	112	51	181	128
No. alive, bud still dormant ...	87	146	16	36
Average height of those shot (inches)	9.9	5.5	17.3	15.1

These results confirm those of the first experiment and illustrate the marked influence of the treatment in speeding up the rate of successful establishment after transplanting.

The beneficial effects of treatment of stumps with growth substance are; reduction in the number of deaths, hastening of the appearance of both roots and shoots, increase in length and weight of the shoot, and increase in the number and weight of roots.*

The initial advantages of early establishment have been maintained in the subsequent growth of the stumps during a period of six months after treatment.

Activation of Cambium

Jost (41) in 1891 discovered the stimulating influence of developing leaves on the growth of the cambium of the stem; the stimulus passing from the leaves to the stem and travelling in a morphologically downward direction. Keeble (42) ascribed this cambial activation to "chemical stimulators" and Kastens (43) suggested that it might be due to a hormone. Experimental evidence of the hormone nature of the stimulus was first produced by Snow (44) in 1933. This last investigator (45) obtained a good activation of the cambium by applying low concentrations (1 to 2 parts per million) of pure auxin-a and indolyl-acetic acid to the upper ends of decapitated Helianthus seedlings.

Van der Weij (46) first demonstrated the presence of hormone in leaves of trees. Hormone has also been extracted from sprouting buds of poplar, willow, oak and horse-chestnut by Czaja (47) and from buds of many woody plants by Söding (48). The presence of hormones in sprouting buds and young leaves and the observed effects of these substances on the activation of the cambium provide indirect evidence that cambial activity in stems of dicotyledons is governed by hormones formed in buds and

**Note*—The method of treatment has been described in detail in the R.R.I. *Planters' Bulletin*, No. 4, 1st June, 1939.

leaves. Moreover, it is known that cambial activity in the branches and stem which causes growth in thickness begins about the time of the sprouting of buds in spring when hormone production is maximum. (Koning (49); Avery, Burkholder and Creighton (50)).

Stimulation of Bark Renewal in Hevea

Indolyl-acetic acid dissolved in lanolin at concentrations of 1 in 1,000, 1 in 5,000, 1 in 50,000 and 1 in 500,000 applied to the tapping panel and directly on to the cambium after stripping the 'bark' has failed to stimulate renewal; the thickness of renewed bark after one year was not significantly different from that of the controls.

The negative results may be due to the high concentrations used or to the physical nature of the auxin 'solvent', lanolin, limiting the access of oxygen to the actively respiring meristematic cells. This explanation would seem to be borne out by the fact that highly significant increases in the amount of bark renewal were obtained by panel treatment with palm oil which, like other vegetable oils, such as maize, sunflower, peanut, linseed and mustard oils, contains free auxin in physiological concentrations.

In another investigation* on the effect of palm oil, and mixtures of palm oil and fungicides, applied to the tapped panel of Hevea trees, significant increases in the rate of growth of renewed bark have been demonstrated during the early stages of renewal.

A common practice on native holdings, which consists in smearing the tapped panel with mixtures of clay (or earth from ant-hills and buffalo pens) and cowdung or mixtures of clay and coconut or other vegetable oil, for the stimulation of bark renewal, would appear to have a sounder scientific basis than was at first supposed. Recent research which has greatly increased our knowledge in the field of plant hormones has shown that plant growth substances are produced by numerous fungi and bacteria and that they occur in animal excrements and in vegetable oils.

Stimulation of Callus Growth

Weisner (51) in 1892 ascribed the regeneration of callus tissue at pruned surfaces (wound-healing) to the action of substances produced by the injured cells which pass into the uninjured cells and stimulate cell division. Haberlandt (52) obtained experimental evidence that these substances are wound-hormones. He showed that the juice from crushed leaves markedly stimulated cell division in uninjured cells. These results have since been confirmed by other investigators.

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* This Journal p. 40 *et seq.*

The presence of wound-hormones has been demonstrated in leaves, fruits and tubers. A plant wound-hormone has been isolated from crushed beans by English and Bonner (53) who named it traumatin. Laibach and Fischnich (54), Rogenhofer (55) and others have observed increased callus growth after the application of a lanolin paste containing indolyl-acetic acid.

Sharp (56), investigating the effect of a number of wound dressings on the rate of healing of snags on large stocks of Hevea, obtained the best results with a mixture of cowdung and clay. Shear (57) obtained good results with lanolin (wool fat) as a wound dressing for pruning cuts on trees and attributed the beneficial effect to its protective action in preventing the drying of the cambium and newly-formed callus. Indolyl-acetic-acid dissolved in lanolin at a concentration of 1 part to 200 parts of lanolin failed to stimulate the growth of callus, presumably because of the high concentration used.

Experiments are now in progress in which pastes of indolyl-acetic acid in lanolin at concentrations of 1 in 5,000, 1 in 10,000, and 1 in 50,000 and lanolin alone are being tested as wound dressings when smeared over the exposed surface after the final pruning of stocks.

Auxin Treatment of Seedlings

The effect of addition of growth substances to the rooting medium has been studied by numerous investigators and somewhat conflicting results have been obtained.

Kögl, Haagen Smit and Erxleben (58) showed that growth in length of roots of oat seedlings immersed in a solution of auxin is inhibited by as low a concentration as 0.1 milligram per litre, while the normal growth of the coleoptile is unaffected. Hitchcock and Zimmerman (59) reported on the effect of indolyl-acetic, indolyl-butyric, indolyl-propionic, naphthalene-acetic, phenyl-acetic and phenyl-propionic acids added to soil in which tomato and tobacco plants were growing. All acids when added at the rate of 10 milligram per pot caused bending of leaves and stems. Higher concentrations, 10 to 27 milligram per pot, caused roots to appear on the main stem, and caused considerable retardation in growth.

Loewing and Bauguess (60) grew stock seedlings in pots and found that addition of 15 c.c. of a 1 in 15,000 aqueous solution of indolyl-acetic acid stimulated the growth in length of the stem. This initial advantage was not maintained and no difference in length of stem between the treated and control plants was apparent ten days later. Greenfield (61) applied indolyl-acetic acid to stock seedlings growing in soil. Concentrations of 0.75 to 3.0 milligram had no effect, 6 to 12 mg. accelerated growth and 48 to 96 mg. caused bud inhibition, leaf bending and thickening and blanching

of stems. Meesters (62) showed that the growth of roots may be strongly inhibited by indolyl-acetic acid at a concentration of 0.5 mg. per litre. Marmer (63) found that addition of the synthetic auxins, indolyl-acetic, indolyl-butyric, and indolyl propionic acids, to water cultures in which wheat seedlings were growing had a stimulating effect on the growth of the primary foliage leaves. Growth in length of the primary root was decreased and the number of secondary roots increased. A concentration of 0.12 mg. per litre caused a 50 per cent decrease in root growth. Pearse (64) added 1 c.c. of a 0.01 per cent solution of indolyl-acetic acid daily for one week to 500 c.c. of the culture solution in which seedlings of broad bean were growing and obtained a marked retardation in growth in length of the roots, although the total root weight remained practically unaltered. The same amount of the growth substances sprayed on to the shoots caused swelling of the stem, bending of the leaves and inhibited the growth of the terminal bud, and root growth was slightly decreased. Shoot growth was retarded by both treatments. Solacolu and Constantinesco (65) found that addition of indolyl-acetic acid to bean and castor oil seedlings growing in solution culture inhibited the growth of rootlets and caused tumours to appear at the collar. Roots were formed from the tumours 24 to 26 hours after transference to an auxin-free culture solution. The same investigators (66) reported a marked stimulation of root growth in pea and bean seedlings in water after a previous immersion in a 0.2 per cent solution of indolyl-acetic acid for 15 minutes. Macht and Grumbein (67) observed a stimulation of root growth of lupin seedlings after a 15-minutes' immersion in a weak solution (1 part in 5 billion) of indolyl-acetic, indolyl-butyric and alpha-naphthalene-acetic acids. Root growth was inhibited by longer exposures or shorter exposures to higher concentrations.

Gautheret (68) studied the effect of indolyl-acetic acid in concentrations of 0.1 per cent to 0.000001 per cent on the growth of seedlings in culture solution. He observed the formation of tumours on roots and a retardation of growth with concentrations of 0.001 per cent and above. Lower concentrations caused extensive branching of the roots. Castan and Chouard (69) found that indolyl-acetic acid at concentrations of 5 to 20 milligram per litre retarded the growth of the main roots of melon seedlings.

Grace (70) reported on the effect of alpha naphthalene acetic acid on nasturtium plants growing in sand culture. The best activation was obtained with a concentration of 1 in 10 millions applied at the rate of 50 cubic centimetres daily for 23 days. The weight of lettuce tops was increased threefold by addition of the growth substance at a dilution of 0.01 part per million of water

at intervals of three days. Smidrkal (71) treated seedlings of celery with 0.01 per cent solutions of alpha-naphthalene-acetic acid, indolyl-acetic acid and indolyl-propionic acid. He obtained increases in root weight of 59 per cent, 64 per cent and 47 per cent respectively. Templeman (72) applied solutions of indolyl-acetic acid, alpha-naphthalene-acetic acid and ascorbic acid (vitamin C) at concentrations ranging from 0.002 per cent to 0.04 per cent to white mustard and barley plants by watering on to the sand in which the plants were growing and by spraying the foliage. He obtained no increases in growth.

The inferences to be drawn from these experiments are that excessively high concentrations of auxin added to the rooting medium result in retardation of growth of both shoot and roots and cause physiological responses such as bud inhibition, bending of leaves and stems, loss of chlorophyll, and formation of tumours on roots. Extremely dilute auxin solutions accelerate the growth of roots.

The effect of pre-treatment of seedlings with auxin is seen in a marked stimulation of growth when the seedlings are transferred to a medium free from auxin. It would seem therefore, that synthetic auxins stimulate the production of roots but retard their growth when in direct contact. Soil treatment is moreover costly, as large volumes of the active solution are required. Evidence has been obtained of the inactivation of auxins in the soil.

Preliminary experiments have been carried out to test the effect of growth substance on the growth of young seedlings of Hevea. The seedlings were growing in baskets and the solution of growth substance was applied to the surface of the soil in the baskets. Twenty-five two-months-old seedlings were treated each with 500 c.c. of a solution of a proprietary preparation at a dilution of 1 in 300 of water. The control consisted of the same number of seedlings treated with 500 c.c. of tap water.

Treatment	Mean Height at Time of Treatment	Mean Height after 3 months	Increase
Growth substance ...	13.1 inches	17.9 inches	4.8 inches
Tap water ...	13.9 „	18.7 „	4.8 „

Twenty-five one-month-old seedlings were treated with 50 c.c. of the solution of growth substance at a dilution of 1 in 150 of water.

Treatment	Mean Height at Time of Treatment	Mean Height after 2 months	Increase
Growth substance ...	10.6 inches	16.7 inches	6.1 inches
Tap water ...	9.5 „	16.0 „	6.5 „

The results of these experiments show no indication that the growth substance has stimulated growth.

Auxin Treatment of Seeds

The practical disadvantages of seedling treatment are not encountered with seed treatment, which consists in soaking the seeds for a specified time in solutions of growth substance prior to planting in the field.

Cholodny (73) has reported large increases in growth and yield as a result of soaking oat seeds in a solution of indolyl-acetic acid (0.01 to 0.02 per cent) for 24 to 48 hours before planting out. Davis, Atkins and Hudson (74) found that pretreatment of oat, mustard and cress seeds with indolyl-acetic acid or indolyl-propionic acid at concentrations of 0.1 per cent and 0.001 per cent retarded germination. Ascorbic acid (Vitamin C) at these same concentrations stimulated germination. Grace (75) observed a stimulation of both root and shoot growth in wheat and barley as a result of seed treatment with indolyl-acetic acid or indolyl-propionic acid or indolyl-butyric acid or naphthalene-acetic acid incorporated in absorbent dust (talc) in concentration of five parts per million. In a further communication (76) Grace reported that the decreased germination and retarded growth of the seedlings after seed disinfection with formaldehyde is largely overcome by treatment of seeds with the disinfecting solution containing 0.01 to 5.0 parts per million of indolyl-acetic acid or naphthalene-acetic acid. Solacolu and Constantinesco (77) found that pretreatment with 0.01 to 0.04 per cent solutions of indolyl-acetic acid retard the germination of bean, cucumber, sunflower, castor oil and pea seed and cause roots to appear on the aerial parts of the plants.

Cajlachjan and Zhdanova (78) reported that soaking seeds of wheat, oat, millet, vetch, hemp, white mustard, perilla, flax and peas for 24 hours in 0.01 per cent, 0.025 per cent and 0.05 per cent solutions of indolyl-acetic acid in water hastened the maturation of the plants produced from them. The growth of oats was accelerated slightly and that of flax and vetch partially or totally inhibited. Thimann and Lane (79) treated seeds of oat and wheat with high concentrations of indolyl-acetic acid (0.01 per cent) before planting in soil and obtained a marked increase in the

percentage germination, in growth in length of the stem, in yield of grain, in dry weight of straw and roots, and in the number of roots formed. Shibuya (80) broke the dormancy in ground nut seed by applying growth substance to the wounded radicle. Amlong and Naundorf (81) claimed that soaking sugar beet seed in 0.175 per cent indolyl-acetic acid for 24 hours prior to sowing resulted in 157 per cent increase in root weight, 129 per cent increase in leaf weight and 123 per cent increase in the total yield of sugar. The percentage germination of twelve poorly germinating seed types was increased by soaking for 24 hours in solutions of each of the following growth substances: indolyl-acetic acid (0.0175 per cent), alpha-naphthalene-acetic acid (0.16 per cent), and indolyl-butyeric acid (0.02 per cent). The increases were 85 per cent, 89 per cent and 106 per cent respectively. Templeman (82) in a series of carefully controlled experiments obtained no growth stimulation after soaking white mustard seed in solution of indolyl-acetic acid (0.005 to 0.05 per cent) or alpha-naphthalene-acetic acid (0.0005 to 0.005 per cent) for 24 hours. The dry weight of the tops was decreased in all cases.

Results obtained by different investigators on the effect of growth substance on the germination of seeds and subsequent growth of the seedlings are conflicting. Incomplete information as to the conditions of the experiment renders judgment difficult. Standardisation of technique, and controlled experimentation by workers on the subject are pre-requisites for a full understanding of the factors involved.

Work on auxin treatment of Hevea seeds to improve germination and the growth of the seedlings is now in progress. Increased germination of seed produced late in the season when the percentage germination is generally low may be of considerable economic importance. Further work on the treatment of seeds of cover plants will also be undertaken.

Other Sources of Growth Substances

The occurrence of plant-growth substances in soil organic matter was first demonstrated by Bottomley (83) who showed that "bacterised peat," peat inoculated with certain aerobic soil bacteria which decompose it rapidly, is a source of substances which stimulate the growth of higher plants. These substances, which are active in very minute quantities, were named by Bottomley "auximones" (Greek *auximos* = promoting growth).

More recent research has shown that such growth substances are in fact produced by numerous bacteria and fungi in soil, in farmyard manure, and in culture. It has been shown that tryptophane, an amino-acid present in plant residues and in excretions of animals, is acted on by bacteria and fungi to produce an auxin,

indolyl-acetic-acid. and that certain fungi in culture produce. besides auxin, other growth-promoting substances such as bios and aneurin (vitamin B_1). The important part played by fungi and bacteria in the decomposition of plant residues may account for the relatively high production of growth substances in farmyard manure and compost heaps. Fungi and bacteria may therefore influence the development of higher plants by producing plant growth-promoting substances.

Certain proprietary preparations consisting of pure cultures of bacteria such a *Azotobacter chroococcum* or *Pseudomonas fluorescens* in a medium of unsterilised peat have been shown to stimulate markedly the growth and yield of plants.

Summary

A brief survey of the literature tracing the development of research on plant hormones is given.

The first isolation of a plant hormone by Went in 1926 and the synthesis of three auxins by Kögl and his co-workers (1931 to 1933) was followed by important work done at the Boyce Thompson Institute in America. This resulted in the discovery that a number of organic acids and their esters not known to occur in plants, and of different chemical constitution from the auxins, are active in stimulating plant growth, and thus led to the practical application in horticulture of the results of academic research in plant physiology. The numerous proprietary "synthetic auxins" now on the market have been developed as a result of this work.

The functions of hormones in plants, their rôle in photo-tropism (response to light), geo-tropism (response to gravity), cambial growth, callus formation, root formation and growth are described and the results of preliminary experiments on Hevea are recorded.

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PALM OIL DILUENT FOR TAR OIL FUNGICIDES AND ITS EFFECTS ON BARK RENEWAL OF HEVEA

BY

F. Beeley and E. D. C. Baptist

Introduction

During early work on the official testing of fungicides for treatment of Mouldy Rot, it was found that some of the more successful fungicides left behind a very thin, sticky film on the bark of the trees which had been treated. In subsequent work in this laboratory, on methods of preparation of emulsions of cresylic acid in water, it was found that the addition of a small quantity of vegetable oil increased the efficiency of the fungicide and had a favourable influence on the rate of bark renewal following its application. Previous work on the use of palm oil on tapping panels had indicated the drawback that the oil film broke down to give a layer of white, oxidised, fatty substances which, to the inexpert, resembled closely the white bloom of the Mouldy Rot fungus. Accordingly our attention was turned to the use of cotton seed oil or linseed oil; the latter, being more readily available, was incorporated in a cresylic acid emulsion known as "Linsocresyl" and proved to be very effective in control of Mouldy Rot. It was also found to have a distinctly beneficial effect on wound healing and on the renewal of bark (See R.R.I. *Annual Report* 1934, p. 95 and *J.R.R.I.M.* Vol. 7, No. 1, 1936).

During the past few years the planting industry has been seeking a method of improving the condition of the renewing bark of some of its older rubber trees which, owing to past treatment and cultivation, had become very thin and hard, so that the usual period of seven or eight years for renewal had failed to give a bark of tappable thickness and soft texture.

Meanwhile, a firm of fungicide manufacturers had become interested in the possibility of using a combined fungicide and bark-renewal stimulant for rubber trees and has produced experimental quantities of a special fungicidal oil of three grades, A, B and C, which when diluted with palm oil might serve the dual purpose of controlling bark disease and stimulating bark renewal.

Consignments of these oils were received in 1937 and arrangements were made to carry out experiments on a field scale on four estates in different parts of the country, representing two coastal and two inland types of soil and climate, to determine the

influence of the fungicide—palm oil mixtures on the renewal of the tapped bark of old, hard, thin-barked trees. Secondly, tests of the fungicidal powers of the mixtures were carried out under the writers' supervision in rubber areas in Selangor which were heavily infected with Mouldy Rot disease of the tapping panel.

Dr. Baptist of the Botanical Division of this Institute who is interested in bark growth stimulants assisted in the execution of the work dealt with in section 3 below and further reference to this experiment will be found in his article in this journal. Sections 1, 2 and 4 and the views expressed therein represent the work of the senior author only.

Experimental

The various tests are conveniently divided into four groups:—

(1) Penetration and burning tests to determine what concentration would be safe to use in the field tests (3) and (4) below.

(2) Fungicides tests in Mouldy Rot disease areas to determine the concentration necessary for effective control of the fungus disease caused by *Ceratostomella fimbriata* (E. and H.) Elliot.

(3) Field experiments including six treatments on each of four estates to study the effect of the treatments on rate of renewal of the tapped bark.

(4) A repetition of three treatments used in (3) above to determine the possibility of eliminating the disadvantages of applications of excessive quantities of palm oil to the tapped bark.

(1) Penetration and Burning Tests

The fungicidal oils A., B. and C. each applied at strengths of 5, 10 and 15 per cent in palm oil to the healthy freshly-tapped panels of rubber trees.

Result. Fungicidal oil A is considered harmful to the inner bark and cambial regions at a concentration of 10 and 15 per cent in palm oil. Latex flow was poor and very watery.

Oils B and C showed slight discolouration of the cambial regions at 15 per cent, at which strength the latex flow from the treated surfaces when cut with a penknife was rather watery. The 5 and 10 per cent concentrations appeared to be safe.

(2) Tests for Efficiency as Fungicides

As a result of tests (1) above and in view of the customary deep tapping in the small holdings area in which such tests are

normally carried out, it was decided not to exceed the 5 per cent strengths of the fungicidal oils which the makers had originally suggested would prove effective. The test plots consisted each of 25 heavily-diseased trees. Treatment by painting the fungicidal-oil palm-oil mixture on the three-inch band of the diseased bark immediately above the tapping cut was commenced on 10.12.37 and the application repeated at weekly intervals, but in this case only the half-inch or so of bark freshly exposed by the week's tapping was treated.

Results. All trees in the treated plots were clear of the active Mouldy Rot fungus after seven treatments. It was found that fungicidal oil A was rather ineffective from the fungicidal point of view during the early period of the test when the weather was very wet.

Oil A showed little control until after 25 days (4 treatments)

Oil B showed over 50 per cent control after 15 days (3 treatments)

Oil C showed about 50 per cent control after 15 days (3 treatments)

The degree of control of Mouldy Rot disease with the fungicidal oils B and C was greater and more rapid than that of oil A.

The treated surface of the bark when scraped with a knife showed good, green, succulent renewal beneath the thin, white film of "decomposed" oil, while the latex flow when the renewed bark was pierced with a knife was fair.

The trees in the control (untreated) plots were heavily diseased, having discoloured bark and large wounds with practically no latex flow from the remaining callus-like bark.

In this experiment the peak numbers of diseased panels occurred during periods not necessarily of heavy rainfall but when, owing to low cloud and drizzle, the sun was unable to penetrate the leaf canopy to the panels below.

(3) Estate field tests of Fungicidal-Oil Palm-Oil Mixtures

For these tests four estates covering widely different conditions of soil and climate were chosen as representative of typical central Malayan conditions. This wide distribution also avoided the necessity of replication and consequent close supervision on each estate.

The estates where managers so kindly undertook this work were,

1. Estate A, Malacca Territory. Inland white alluvial soil, dry climate.

2. Estate B, Port Dickson, Negri Sembilan. Coastal hill soil, average climate.

3. Estate C, Klang, Selangor. Coastal, peat soil, average climate.

4. Estate D, Ulu Selangor. Inland hill areas, average dry climate.

In co-operation with the Botanical Division of the Institute it was decided to include six treatments on each of the four estates as follows:—

1. Fungicidal Oil A. 5 per cent: Palm Oil 95 per cent

2. Fungicidal Oil B. 5 per cent: Palm Oil 95 per cent

3. Fungicidal Oil C. 5 per cent: Palm Oil 95 per cent

4. White Fluid fungicide 3 per cent in water as at present advised for control of Mouldy Rot.

5. Palm Oil alone.

6. Control, untreated, observation task.

Each treatment in these experiments covered one tapping task of about 300 trees. Selected tasks were adjacent to each other and in an area with as little natural variation as possible. The trees were in all cases old with rather poor, hard, renewed bark.

The treatments were applied at weekly intervals, when the lowest three inches of the newly-tapped bark were brushed over with the various preparations.

Measurements of bark thickness at three points just above the tapping cut on each of 50 marked trees throughout each task were taken before commencement of the treatment in November 1937 and at intervals of about three months thereafter.

It was unfortunate that in the early stages bark measurements were taken by two field conductors and owing to the breaking of one of the instruments one of a different type was introduced. It was subsequently found necessary to make corrections for the difference in readings of the two types of instruments, which was kindly undertaken by the Statistician and the Botanist, so that the figures presented in the table of summaries of results may be taken as strictly comparable throughout.

At the same time as the second series of bark measurements were taken on the original marked positions of the tapped panel a second line of three points was taken, again just above the tapping cut, which, as a result of the progression downwards of the tapping cut, was about three inches below the first line of

measured points. This amounted to a duplication of the experiments and has fully confirmed the figures of the rate of renewal at the higher level on the panel.

Both series of measurements indicate that after seven months' treatment the fungicidal oils and palm oil mixtures and the palm oil alone give highly significant improvements in bark renewal over the control and the white fluid treated plots. It is of interest to note that comparatively little difference was recorded in the effect of the fungicidal oil A as compared with that of oils B and C, all being equally good and that the white fluid treated plots showed in some cases inferior bark renewal to that of the control plots.

Growth in bark thickness in mm. for each period:—

Treatment	Treatment means (mm.)		
	d 1	d 2	d 3
Palm Oil	2.51	.93	2.36
Palm Oil—Fungicidal Oil A ...	2.71	.72	2.43
Palm Oil—Fungicidal Oil B ...	2.90	.82	2.42
Palm Oil—Fungicidal Oil C ...	2.87	.88	2.37
White Fluid	2.42	–.01	1.81
Control	1.97	12	1.66
Standard error	.188	.134	.098
Mean Growth	2.56	.58	2.17

Where d 1 = { growth in bark thickness in mm. Oct.—Nov. 1937 to February 1938.

Where d 2 = { growth in bark thickness in mm. February to June 1938, *i.e.* from the fourth to the seventh month after tapping and first treatment.

Where d 3 = { growth in bark thickness in mm. on a second line taken on freshly-tapped and treated bark on the same trees but some three or four inches lower down the panel for the period March to June 1938 (three months).

The differences between the first four treatments are not significant.

The differences between the white fluid treatment and control are not significant.

The differences between the four palm oil treatments and control are highly significant.

The differences in growth of bark with and without palm oil during the three periods observed appear to be appreciably different at the various estates during each period. The excess of growth in plots receiving palm oil over those not receiving it was as follows:—

Estate	Excess Growth (in mm.)		
	d 1	d 2	d 3
A	.23	.94	1.08
B	.98	1.37	.48
C	–.09	.84	.97
D	1.09	–.01	.12
Standard error	.326	.233	.169
Mean	.55	.78	.66
Standard error	.163	.116	.085

Allowing for this possible interaction the analysis of variance is as follows:—

	d. f.	Mean Squares		
		d 1	d 2	d 3
Palm Oil ...	1	1.6317 ss	3.3813 ss	2.3320 ss
Fungicidal Oils ...	4	.1975	.0332	.0158
Estates ...	3	3.2572 ss	1.0937 ss	.7188 ss
Palm Oil x Estates ...	3	.4398 ss	.4480 ss	.2691 ss
Remainder ...	12	.1418	.0723	.0382

ss = highly significant.

In the above tables the plots treated with white fluid and the plots receiving no treatment (control) are together taken as plots receiving no palm oil.

The analyses of variance show that the effect of palm oil, and the interaction between estates and the palm oil treatments are each highly significant. Differences in growth due to presence or absence of fungicidal oils are not significant.

It is unfortunate that further replications of the experiments were not carried out at a larger number of centres so that some correlation might have been obtained regarding the effects of palm oil on growth under various soil conditions and climates.

Mean growth of bark in the various intervals on the four estates were as follows:—

(a) Without Palm Oil

Estate	Mean Growth (mm.)			Soil Type
	d 1	d 2	d 3	
A	1.87	.42	1.63	Flat alluvial
B	2.12	–.285	1.36	Undulating red soil
C	2.00	.06	1.81	Peat—flat
D	2.78	.02	2.12	Granite hill soil
Standard error ...	.266	.190	.138	

(b) With Palm Oil

Estate	d 1	d 2	d 3	Soil Type
A	2.10	1.36	2.72	Flat alluvial
B	3.10	1.100	1.84	Undulating red soil
C	1.91	.90	2.78	Peat—flat
D	3.88	.00	2.24	Granite hill soil
Standard error ...	.188	.134	.098	

(c) Rainfall figures for the four districts are as follows:—

Estate	d 1 Nov.—Feb. 1938	d 2, d 3 Mar.—May 1939
A	26.88″ on 43 days	29.13″ on 55 days
B	23.66″ on 43 days	15.87″ on 35 days
C	20.93″ on 66 days	23.51″ on 47 days
D	33.42″ on 70 days	37.35″ on 64 days

Comparing the growth of bark in columns d1 and d2, which each represent the early period of renewal of bark after tapping,

there is strong indication that better growth of bark with or without treatment generally occurs during periods of higher rainfall or when wet days are more frequent. During such periods the increase in growth in the palm-oil-treated plots over those not receiving palm oil is not so apparent. Also the rate of growth of bark on hilly land is slowest during dry periods when the palm oil appears to have maximum effect. On Estate B, following a dry February and light rains in March, April and May, a shrinkage of bark occurred during the period d2 in the untreated plots, while the palm-oil-treated plots put on a further 1.10 mm. of bark. On estate D the more equably wet weather appears to have promoted growth of bark to such a degree that the differences in the treated and untreated plots are less marked, except during the monsoon period (d1) when heavy rains followed by bright dry periods are usually experienced in this district. On the flat lands of Estates A and C the effects of the treatment are less marked during the monsoon weather of the period d1, when rapid flooding and rapid drying-out of the soil occurs, but are well marked and of a more constant character during the more equable climate of the periods March, April and May (d2 and d3).

From the above it may reasonably be concluded that two distinctly different factors are at work when palm oil is applied to the bark of tapped rubber trees, the one a hormone factor which promotes cambial activity and growth, the other a physical factor, the prevention of excessive evaporation of moisture from the inner cortex exposed by the tapping process. Further experiments on the influence of growth hormones and other factors are being undertaken by the Botanical Division of the Institute, which may throw further light on this interesting problem.

All the above plots treated with the palm oil and palm oil mixtures showed a disappointing feature. The outer renewed bark had been killed inwards in successive layers. The subsequent weekly applications of the mixtures resulted in an accumulation of oxidised. fat decomposition products on the bark surface which in turn resulted in the death of successive layers of bark. In spite of this, however, the living, latex-bearing bark below compared very favourably with that of the best trees in the control plots.

The thickness of renewal after three months' treatment was 25 to 50 per cent greater in the case of the trees treated with palm oil and its mixtures with fungicidal oils as compared with that of the controls.

The second series of measurements taken during the moderately dry mid-year months strongly support the above conclusions, and again 25 to 50 per cent better renewal of bark was obtained in the plots receiving treatment with the palm oil and palm oil

mixtures; in fact, in trees so treated both the bark and the soft wood beneath appear to be so improved as to cause an obvious swelling of the trunk of the tree in the treated zone.

The disadvantages mentioned above of applying excess palm oil to the surface now had to be overcome, as no other drawbacks appeared to be in evidence save that of the tendency to wound the bark during tapping owing to the induced softness of the bark and the slipperiness of the oiled surface. To this end the following test was carried out.

(4) Repetition of Part of Test No. 3

This test was a repetition of part of test No. 3 and consisted of three treatments only, each over one task on each of the four estates.

(1) Fungicidal Oil "A" 5 per cent—Palm Oil 95 per cent.
(2) Palm Oil alone.
(3) Control.

Treatments were carried out weekly as before but in this experiment, while a three-inch zone was treated at the commencement, only a half-inch strip was painted subsequently at weekly intervals so as to avoid overlapping and consequent excess of oil on the panel.

Bark measurements on 50 trees in each task were taken just before the first treatment and three months later.

Result. This experiment has shown that it is possible greatly to reduce the disadvantages found in Experiment 3 and still maintain 25 to 50 per cent increase in thickness of renewed bark by application of palm oil as compared with the untreated plots. In the experiment on Estate B, where the figures are not so significant, it was found that treatment had been given over a period of five weeks only, after which stocks of fungicidal oil and palm oil had run out and the experiment was discontinued.

However, on the remaining three estates the improvement in the renewal as shown by the statistical analysis below is again highly significant.

Growth in bark thickness over a period of three months:—

	Treatment means (mm).
1. Palm Oil	2.23
2. „ „ Fungicidal Oil A.	2.07
3. Control	1.07
Standard error	.065
Mean Growth	1.79

Difference (Palm Oil—No Palm Oil) = 1.08 ± .080 which is very highly significant. The mean initial thickness of bark was 2.43 mm. which is usual for good estate tapping.

Conclusions

(1) The application of controlled quantities of palm oil to the freshly-tapped bark of old hard-barked rubber trees improves the subsequent renewal of bark to a very significant degree. It is not shown that the renewal of bark of young vigorous trees will be similarly stimulated.

This effect of palm oil is claimed by one of us to be due to the presence of physiological quantities of growth hormones which occur in most vegetable oils including linseed oil, which is also known to have a beneficial effect on rate of bark renewal.

It would also appear that the more rapid and succulent development of the renewing bark following treatment of the tapped panel is due to some extent to the oily layer preventing excessive evaporation of water from the delicate inner cortical tissues exposed by the tapping process. This is supported by the fact that a similar though inferior development of bark may be obtained following the application of mineral wax to the exposed surface of the cortex. This treatment, however, cannot be generally adopted in the tropics, as the sun's heat melting the wax causes excessive penetration, blocking of lenticels and subsequent choking of bark surfaces so covered. The use of wax, solar oil—tar oil mixtures for treatment of panel diseases is however popular in some districts where the foliar canopy is sufficiently dense to prevent prolonged heating of the tapping panel surface.

(2) The inclusion of the fungicidal oils A, B and C in the palm oil is of no added advantage unless it is required to control panel diseases.

(3) Fungicidal oil at 5 to 10 per cent in palm oil would be a suitable mixture for treatment of Mouldy Rot disease of rubber trees, acting both as a fungicide and as a promoter of bark renewal.

(4) The application of excessive quantities of palm oil to the panel may have certain disadvantages which, however, can be overcome in ordinary rubber estate practice by avoiding any overlapping of a previously treated section of the panel during subsequent treatments.

Summary

An experiment is described in which the benefits of using palm oil as a diluent for fungicides for application to the tapped panel of rubber trees are determined. The significant influence of this vegetable oil on rate of bark renewal has been demonstrated.

Acknowledgment

We wish to thank the managers of the estates who so kindly undertook the experiments.

We are specially indebted to Mr. H. Fairfield Smith for the statistical analysis of the data.

Kuala Lumpur

20th June 1939

A NEMATODE PEST OF ROOTS OF COVER PLANTS

BY

F. Beeley

Introduction

During the past few years the writer has inspected many areas planted with leguminous cover plants in his endeavour to obtain cultures of the nodule rhizobia of the various species of legumes commonly grown as cover plants on rubber estates. It was very soon noticed that many species of legumes which were reported to bear good nodules proved on investigation to bear large root swellings in which the presence of female nematodes, their eggs and larvae, could easily be demonstrated.

Although cultures of the true nodule organisms (*Rhizobium* spp) for the smaller creeping legumes were easily obtained, great disappointment was experienced in the search for beneficial rhizobia of the more coarse creepers and bush legumes such as *Pueraria* sp. *Calopogonium* sp. *Desmodium ovalifolium*, *Tephrosia* sp. and *Crotalaria* sp., in all of which it was frequently found that the large nodules on the roots, thought to be rhizobia nodules, were usually of the root-knot type caused by an eelworm endoparasite.

At the Rubber Research Institute Planters' Conference in July, 1938, further attention was drawn to the possibility that this pest might be responsible for the failure of legumes as cover plants in rubber estates. Since the Conference numerous cases of such failure of legumes have been reported and have been found on investigation to be due to the ravages of this eelworm root pest. Up to the present time a large number of species of cover plants and some indigenous covers have been found to be susceptible to attack by this root-knot eelworm and the following description of the pest and its method of attack of the cover plants in rubber areas is presented.

Causal Organism

The species of eelworm causing the root-knot disease of cover plants in Malaya closely resembles *Heterodera marioni*, (Cornu), Goodey, which belongs to the subfamily *Anguillulininae* of the main family *Anguillulinidae*, Order *Eunematoda*, Ward.

The nematodes or, as they are commonly known, eelworms or roundworms, are classified by zoologists in the phylum *Nemathelminthes* and belong to the animal kingdom.

Life History

Adults

Commencing with the adult nematode the mature female measures 0.4 mm. to 1.3 mm. long by 0.27 mm. to 0.75 mm. wide the average size being 0.8 mm. long by 0.5 mm. wide. The neck and tapering head region is distinctly narrower and is about one-third of the whole length. The posterior part of the body is rounded and the vulva region is not prominent as in *Heterodera schactii*, of which the female is distinctly lemon-shaped. The female lies and develops within the tissue of the gall. The eggs are laid into a gelatinous mass which becomes firmly attached to the body wall and gives the very white appearance to the worms when freshly dissected from the root galls.

The number of eggs laid per female depends to a great extent on conditions and may reach the thousand mark if such are ideal. Parthenogenetic reproduction appears to be normal for the species, while males are produced in heavily parasitised roots or under conditions unfavourable to the parasite.

The males are about 1.2 mm. to 1.5 mm. long by 0.03 to 0.36 mm. wide. The body is worm or thread-like in shape and is difficult to see with the naked eye, whereas the globular white female is fairly easily visible without the aid of a lens.

Larvae

The eggs, which are ellipsoidal in shape and slightly concave on one side, hatch out in a few days to produce the first-stage larvae, which are very small and thread-like, reaching lengths of one-third to one-half millimeter.

The larvae make their way into the roots, preferably near the delicate root tips, or if hatched within a gall they make their way deeper into the root tissue towards the source of food or may pass out of the gall into the soil in search of fresh roots.

According to Goodey (1), having taken up a position within the root the larvae become stationary and quickly begin to increase in thickness especially in the region of the body lying between the aesophagal bulb and the anus. After about seven to ten days this part becomes cylindrical in shape, the tail remaining narrow and pointed. A new cuticle is then laid down beneath the old one and within this the male is produced lying coiled on itself parallel to the long axis.

PLATE I

Top — Diagramatic representation of a nematode root gall on left and a true nitrogen nodule on right.

Below — Photograph of two female and three male nematodes, extracted from a root gall. (Magnification x 50)

The females develop by stages in a similar fashion within the new cuticle, but the body is not coiled and occupies the bulk of the old larval cylinder.

Depending upon conditions the whole life cycle may be completed within about five weeks.

Symptoms and Environmental Influences

Symptoms of Attack

As a rule the attack is not discovered until some above-ground symptom strikes the eye as being abnormal. The usual above-ground symptoms of attack are:— (a) foliage changes to a yellow colour in small, usually low-lying areas of the field, eventually becoming rather sparse, (b) general weakening of the stems is noticed especially in the case of bush or shrub covers, so that they are readily attacked by other secondary parasites such as mosses, lichens and algae. Thus, in the more woody upright covers the aerial symptoms can easily be detected. But, in creeping covers where frequent nodal rooting takes place, as the creeping stems grow and travel over the ground the new roots not yet heavily attacked may support the life of the newer portions of the creeper, so that a serious attack of the eelworm pest may go undiscovered for many months. When eventually the pest takes the upper hand the creeper appears to die rapidly and mysteriously.

It should be noted that many of the leguminous covers used in Malaya exhibit a characteristic yellowing and loss of foliage during the wintering season of February and March, and possibly again in July and August if these months are exceptionally dry. During these dry periods it is also found that the older nodules disintegrate and become hollow with a typical round hole at the distal end. On return to normal weather conditions new rootlets are grown on which new nodules develop, after which the plant soon produces its normal, deep green foliage.

It is therefore impossible to diagnose the presence of an eelworm pest simply by an examination of the foliage, but reference to specimens of mature roots usually enables a rapid diagnosis to be made. Here again it is necessary to stress the need for examination of mature roots, several months old, for the reason explained above, that in creeping covers specimens of living stem and roots of leading runners may appear perfectly healthy while the old roots from older nodes will show heavy infestation by the pest.

An examination of the roots of the attacked covers reveals the ugly galls or root swellings from which, if cut with a pen-

knife and lightly squeezed, the white bead-like females emerge. The root galls can be readily distinguished from true nodules by their structure; the former are true swellings, the root continuing on through the swelling and may form other galls a short distance away, which, growing rapidly by irritation of the root tissue, may eventually fuse one with another. The true nitrogen-fixing nodule is of definite spherical or bean-shape, is produced on a root hair laterally to a feeding root, and has no continuation of the rootlet at its distal end. The diagrammatic illustrations attached make this differentiation quite clear.

In size the true nitrogen nodules may be from one-tenth inch to four-tenths inch diameter and have a bright natural colour; the eelworm galls may reach much greater dimensions, but are irregular in shape, the surface becoming dark and stained with age. The accompanying photographs illustrate the form of root damage caused by Heterodera on the following specimens of covers. Magnification approximately half natural size.

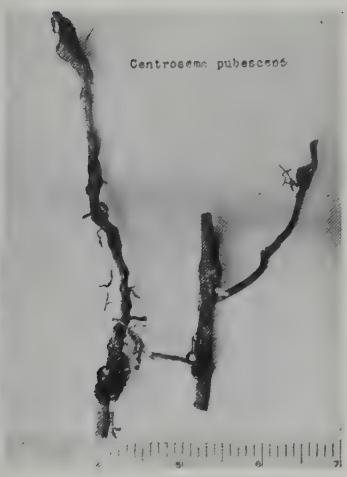
Clitoria sp.
Tephrosia candida
Tephrosia maxima
Passiflora foetida
Desmodium ovalifolium
Calopogonium mucunoides
Centrosema pubescens
Indigofera endecaphylla
Mimosa invisa
Pueraria javanica

The indigenous cover *Callicarpa longifolia* (N.O. *Verbenaceae*).

For comparison, a photograph of roots of *Centrosema pubescens* bearing true nitrogen-fixing nodules two thirds natural size is shown at the top right hand of Plate II.

Unlike certain other species of nematode *Heterodera marioni* shows no host specialisation and among susceptible species this pest appears to be able to transfer its activities from one host to another indiscriminately. Already over eight hundred species of plants are listed as being parasitised by this species of root-knot nematode. Though practically all known species of cultivated cover plants appear to be more or less susceptible to attack it is not known to what extent indigenous plants are so parasitised, though it seems likely that most species of forest plants will show evidence of resistance developed over a long period of years.

PLATE II



Top Left — Nematode galls on roots of *Centrosema pubescens*
Top Right — True N-fixing nodules of *Centrosema pubescens*
Bottom Left — Nematode galls on roots of *Calopogonium mucunoides*
Bottom Right — Nematode galls on roots of *Pueraria javanica*

PLATE III

Top Left — Nematode galls on roots of *Mimosa invisa*

Top Right — Nematode galls on roots of *Passiflora foetida*

Bottom Left — Nematode galls on roots of *Clitoria* sp.

Bottom Right — Nematode galls on roots of indigenous cover *Callicarpa longifolia* N.O. Verbenaceae.

Top Left Nematode galls on roots of *Tephrosia candida*
Top Right Nematode galls on roots of *Tephrosia maxima*
Bottom Left Nematode galls on roots of *Desmodium ovalifolium*
Bottom Right Nematode galls on roots of *Indigofera endecaphylla*

Environmental Influences

The eelworm *Heterodera marioni* shows a tolerance for a wide range of temperature and moisture conditions.

Though in temperate climates this species is spoken of as a greenhouse pest it can also exist actively in soils which may be subject to freezing. It is however most active in tropical and subtropical soils ranging in temperature from 15° to 25°C, while even higher temperatures can be tolerated.

Similarly, wide ranges of moisture tolerance are shown by this pest and, while waterlogging or flooding the soil, or drying out the soil by fallowing and exposure to sun and wind will tend to reduce the vigour of the parasite and reduce the extent of gall formation, it is generally found that wherever moisture conditions in the soil are suitable for the growth of plants they are also favourable for activity of the eelworm pest.

It has, however, been observed that during the dry years more eelworm damage to crops in Malaya has been noticed and this has probably been due in part to an increase in degree of infestation and partly to a reduction in drought resistance occasioned by depletion of effective root area due to presence of eelworms.

Though both hill and flat areas have been found to be infested with the pest in Malaya this species shows a preference for deep light alluvial or sandy loam soils well aerated and well drained. Heavy clays or stiff clay-gravel soils do not appear to favour eelworm infestation. Loamy hollows between rolling hills of firmer soil are usually more heavily infested than the hills.

From root observations it would seem that the pest is most active in the top foot or so of soil, which is the region also containing most roots, but root galls have been found at greater depths in very light soils.

Thus it is found that in view of its tolerance for wide ranges of temperature, moisture and soil, there is little hope of using extremes of such conditions as measures of control of the pest. Such extreme conditions merely reduce the gall-forming activity of the pest and if adopted under estate conditions would probably tend to do more harm to the growing crop than to the pest.

Control

It is unfortunate that no practical economic method of control of this parasite where land is under tree or other perennial crops has yet been found. However, since Hevea, the main crop, is apparently resistant to attack, control measures need be directed only against control of the pest on the cover plants, and with this in view the following suggestions are put forward.

1. First inspect all cover crop nurseries or areas from which cuttings of cover plants are to be taken, in order to make sure that such areas are not infested and that the pest is not therefore spread by the cuttings to other areas which may not be infested. No movement of plants or soil from an infested area should be permitted. Isolation drains as suggested in some quarters are no barrier to the spread of eelworms.

2. On areas already infested the covers should be uprooted carefully with forks and burned, paying special attention to the destruction of the galled roots. The area may then be replanted with a less susceptible or immune species of legume cover or, if possible, indigenous cover plants may be allowed to establish themselves. As mentioned above the finer creeping covers are more resistant to eelworm attack than the woody covers, and instances are known where *Centrosema pubescens* has formed a satisfactory cover after the death of stronger covers from eelworm infestation. The legume species *Abrus precatorius* L. (paternoster bean), *Cajanus indicus* Spreng (pigeon pea), *Crotalaria juncea* L. (sun hemp), *Desmodium molle* D.C. (Florida beggarweed), *Phaseolus lunatus* (lima bean), have all been found to be attacked by the pest but, unlike the majority of species, they show some resistance to attack and might therefore be used satisfactorily as covers in infested areas.

Attack by *Heterodera marioni* does not appear to have been observed or reported on the species *Derris elliptica, Derris malaccensis, Tephrosia toxicaria, Desmodium triflorum, Pachyrhizus angulatus.* These, therefore, are possible species for experimental testing in known heavily infested areas. Experiments with these species of covers are to be carried out in heavily infested, flat, alluvial soils in the Institute's Experiment Station, Sungei Buloh.

3. Chemical methods. Sterilisation by dry heat or steam is feasible for small quantities of soil for pot-culture work but is quite impracticable under estate conditions. It is also found that chemical disinfectants, larvicides and poisons, though affording a certain measure of control, are not economic in practice. The parasite living within the root tissue is difficult of access by the chemical except in concentrations which may prove lethal to the plant itself; this accounts for the resultant very high cost of such treatment. Formaldehyde, para and orthodichlorbenzene, cyanides, carbon bisulphide and similar soil fumigants have been tried without notable success.

Heavy dressings of calcium cyanamide are said to afford a check on the activity of eelworms on roots in the soil.

The nematode pest is worthy of the serious attention of planters in this country, because it is capable of rapid development

and spread under normal Malayan conditions; it is capable of destroying large areas of covers, rendering the soil unfit for growing other species of covers, and because the eradication of the pest is either impossible or too costly.

On the other hand, it is not intended by this investigation to discourage the use of leguminous covers on rubber estates but to indicate a further possible reason for failure of establishment of legumes and to show how infestation can best be avoided on areas already free of the pest.

General remarks on planting of covers in new or replanted areas

It is impossible to tell without a root inspection of the forest plants whether a given area is infested with eelworm or not, but from experience it seems probable that the alluvial flats carry an original infestation while the hills and clay flats are comparatively free from the pest. Care should therefore be exercised to ensure that infestation is not carried to the new areas, and as far as possible covers should be sown and not planted in the form of cuttings which may have come from an infested area. Replanted areas where the previous rubber crop had been under clean-weeded conditions for many years in the past, would probably be fairly clear of infestation, and the same precautions to keep them clear of the root-knot pest should be exercised.

When the cover has been growing for about a year or more some of the older stolons and roots should be carefully dug up and inspected for the presence of root galls. If galls are present the area of infestation should be determined by exploration and the infested cover eradicated and burned. A more resistant species of cover may then be sown.

In areas reaching maturity, where the rubber canopy affords ample shading of the soil from the fierce sun, the possibility of bare fallowing or clean-weeding being used for controlling the pest by starvation may be considered in areas where terraces, contour bunds and bunded pits are available for the prevention of undue soil erosion.

Summary

In this article attention is drawn to a serious eelworm pest of cover plants in Malaya. The species of nematode concerned appears to be *Heterodera marioni*. Most species of legumes normally planted as covers have been found to be susceptible to attack, though some species are more resistant than others and

may afford a means of establishing suitable ground covers in infested areas. A species of indigenous cover in an experimental area has also been found attacked by this pest.

There are no satisfactory economic methods of controlling this pest, so that methods of prevention of spread of the pest and experiments to discover resistant and possibly immune species of legumes are suggested as affording a reasonable solution of what may prove to be a serious problem in the establishment of leguminous covers in some of the light alluvial soils of Malaya.

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Kuala Lumpur,

25th May, 1939.

OIDIUM HEVEAE

A Report on the 1939 Outbreak

BY

F. Beeley

The year 1938 proved a very dry year for most districts of Malaya. Even the usual monsoon rains normally experienced towards the end of the year failed to materialise and many new plantings carried out during this recognised planting season suffered badly from drought. As a consequence it was thought that with the usual bright dry weather of late January and February of 1939 an early wintering and healthy refoliation would occur early enough to avoid the onset of the usual dull weather and mildew in mid-March.

However, January and February were not so dry as might have been expected, in the absence of dry north east monsoon winds local conditions had the greater effect on weather. Bright days with occasional local rain persisted throughout, so that the local evening rain proved heavy enough to make wintering very slow and ultimately some three or even four weeks later than usual. In spite of this, regular bright mornings and afternoons favoured rapid refoliation in most districts with scarcely a sign of leaf mildew on the foliage. However, in the great majority of areas examined, the early blossom was so heavily attacked that the amount of seed set will probably be very small. At the time of writing this report—mid-May—there is a considerable amount of healthy second blossom present in most districts which will probably ensure a fair though late, seed harvest.

Continuous daily, microscopic observations on buds, new leaf and flowers of an area of rubber adjoining the laboratories were carried out during the wintering and refoliation season. The buds and new flowers and leaves remained perfectly healthy up to March 15th when some 20 per cent of trees in the area had obtained their complete canopy of foliage. On the 15th however, the flowers were suddenly observed to be very heavily infected and on the morning of that day conidia were observed bearing chains of spores up to seven in number. This followed a break in the weather on the 12th and 13th when dull mornings and light rains were experienced in Kuala Lumpur. Mildew first appeared on the very young foliage in this area two days later on March 17th and a few individual leaves were sufficiently seriously attacked to be killed and thrown off later. After this short dull period the weather continued bright with evening showers and only on about one day per week was morning cloud or drizzle experienced and

this appeared to be inadequate seriously to upset the wintering or to increase the incidence of *Oidium Heveae* sufficiently to cause a serious leaf fall in any part of Malaya. In many districts the foliage of the older rubber is of the large size and deep green colour with glossy upper surface normally associated with trees of much younger age. Continuous microscopic examination of fresh specimens of foliage has again failed to reveal any resting spore stage in the life history of the fungus. Its sudden appearance simultaneously on several trees, each in the same stage of refoliation, over widely different parts of the same clearing, again indicate a form of hibernating fungus as the most likely stage in which the disease is carried over from year to year. The hot weather and intermittent evening showers appear to have been more favourable to the incidence of mites, spiders, thrips and leaf-spot fungi than to *Oidium Heveae*. About one-third of the total number of specimens of diseased leaves sent in for examination proved to be cases of attack by these pests.

TABLE I

Reports received per week from each State or Settlement

	March		April			May		Total
	14th 21st	22nd 28th	29th 5th	6th 12th	13th 19th	20th 26th	27th 4th	
Johore ...	—	—	7	1	4	2	—	14
Malacca ...	—	2	2	1	—	—	—	5
Negri Sembilan ...	3	5	11	3	3	6	5	36
Selangor ...	1	1	5	1	9	—	4	21
Perak ...	1	3	4	4	2	—	—	14
Province Wellesley ...	—	—	—	—	1	—	—	1
Kedah ...	5	—	5	—	—	—	—	10
Pahang ...	—	—	—	—	1	—	—	1
Total ...	10	11	34	10	20	8	9	102

On the whole, wintering, though slow, was a very good one, vast areas of trees presenting a very bare appearance especially in the north of Perak, Province Wellesley and Kedah where winter-

ing was several weeks earlier and rather more severe than in the south, where a mild though more general incidence of leaf mildew occurred.

The number of reports of the disease from estate managers at 102 is a considerable reduction on the number (129) received last year and correctly indicates the better condition of the new foliage this season. As in previous reports the accompanying table shows the time of first noticed mildew attack in the various States. The absence of reports of leaf-mildew in February and the first two weeks of March indicates the lateness of the wintering and of the incidence of disease.

In Selangor and Negri Sembilan the lateness of wintering resulted in the persistence of a late attack of leaf mildew into the first week of May.

Though a number of estates were prepared to carry out sulphur-dusting, this hardly proved necessary and dusting programmes were restricted to two or three rounds during the height of the refoliation period.

The incidence of *Oidium Heveae* on the flowers has been so noticeable this year that many requests were received for the loan or purchase of hand dusting machines from managers of budded areas from which a good seed crop is expected. The writer would advise all managers in charge of such areas to equip themselves with a small dusting machine and supplies of sulphur for the protection of the blossom and to carry out dusting at five-day intervals from the time of commencement of flowering. There is no easy method of determining the precise time of first attack of flowers in the field and by the time the leaves show the typical symptoms the flowers, being attacked so much earlier and more virulently will probably have been killed. Hence, protection of the flowers can only be ensured by dusting from the time of commencement of flowering.

The writer made his usual tour of inspection of the rubber-growing districts west of the main range in order to ascertain the extent and severity of the leaf mildew disease and the quality of the new foliage. He is again indebted to those managers of estates who sent in reports both of the occurrence of the disease and gave particulars regarding the percentages of trees attacked and local weather conditions which have helped to formulate the district reports given below.

Johore

Although Johore, along with the rest of the Peninsula, experienced a rather drier monsoon period in November and December the heavy rains experienced in January tended to delay the winter-

ing of the rubber trees in this State, especially in the Central and Southern parts. However, the hot dry weather of February and early March induced wintering of a severity rarely seen in this State, the completeness of the wintering being marred by the presence in many areas of trees with old green leaf which had probably wintered in the dry period of August last year, and would consequently be very late in their wintering at this season.

On the whole, the wintering was three weeks later than is usual for this State. At the time of the visit during the last week of April, in the south the foliage was very good with an excellent deep green colour and glossy leaf surface. Occasional trees wintering late had been attacked and had suffered a little leaf-fall in the lower, shaded branches. In central Johore the wintering had been rather mixed and though the earlier wintering trees had obtained a good foliage the main body of the late trees had suffered a mild attack with consequent partial defoliation.

The northern districts appeared to be in better condition and had put on new foliage which is generally thought to be the best for many years, though occasional areas carried trees which appeared to have wintered and refoliated in August last year. The clean-weeded areas with bunded silt pits located in this district have obtained a particularly excellent foliage this year, probably as a result of the earlier wintering which usually takes place on such areas compared with areas under heavy natural or leguminous covers.

A number of reports were received from this State of damage to foliage by mites, thrips and leaf-spot fungi. This was verified during the tour and observed to be common in the younger rubber areas.

Malacca Territory

Throughout this State the period November 1938 to March 1939 had been drier than usual; in January the fine dry weather had begun while February was exceptionally fine and dry with a rainfall of only 2.3 inches.

As a result of this dry period the wintering was exceptionally severe and healthy new leaf was obtained in most districts before the break in the weather in mid-March. Local weather conditions had however delayed the refoliation of some areas and while in the north of the State, Tampin and Alor Gajah districts were in good condition, considerable leaf-fall caused by *Oidium Heveae* was observed in the Jasin and Asahan districts. This was thought to be due to a large number of the trees having wintered abnormally in August last year and these were late wintering in the present season.

The southern parts of the Territory though comparatively free of mildew at the time of inspection its presence was indicated by defoliated lower and central branches. On the whole however an excellent top foliage has been obtained, and only sudden brief attack in the Central and Southern areas is recorded.

The number of reports of occurrence of the disease shows a further decrease on the number for 1938.

Negri Sembilan

After a comparatively dry year the November—December monsoon rains proved very disappointing and in many districts in this State less than half the usual amount of rain fell at this period. During the comparatively fine dry month of January a very severe wintering was induced but its progress was delayed by the occurrence of heavy showers at favourable intervals throughout the month. However, by the middle of March up to 50 per cent. of trees had obtained new foliage on inland soils, while the coastal flats were rather later with only 20 to 30 per cent. of new foliage and a few trees still partially wintering. By the end of April refoliation was complete and assisted by further periods of bright weather the foliage had easily survived a mild attack of Oidium. The number of reports of the occurrence of the disease shows a further decrease on last year's number.

In the more undulating and hilly districts, north of Seremban, Nilai and Port Dickson, the foliage was particularly good and signs of leaf-fall could only be observed in lower branches of late wintering trees often close to root disease areas or old bungalow sites. It has often been noted that trees on the edge of an open clearing appear to suffer more severely from *Oidium Heveae* than trees well within the plantation.

The southern inland areas of this State also exhibited excellent rubber foliage, but it was noticeable that a second growth flush was occurring at the time of inspection (end of April) and that most of this second foliage was of a pale colour. Closer investigation revealed that this was due to attack by Hevea thrips and in some cases by mites. The districts of Johol, Kuala Pilah and Bahau at the foot of the main range, had apparently experienced a later and less severe wintering; though the earlier foliage was quite healthy, a fair proportion of the later wintering trees had suffered attack by the leaf mildew fungus with consequent defoliation of middle and lower branches. Some areas were better than others, the western slopes of hills having suffered the most.

Younger rubber in the Rompin and Bahau districts appeared to have a very heavy canopy of foliage and much second growth was occurring and again the presence of insect pests was noted.

The general improvement in foliage throughout the State did not afford any distinction between normal areas or different clones, such differences as were noticeable being due to topographical conditions and local weather conditions at the time of refoliation.

Several estates carried out modified programmes of sulphur dusting during the refoliation season, but though some of the dusted fields had a slightly better lower foliage than undusted areas the ultimate benefit of the dusting will probably show in the seed harvest. Throughout the western part of the Peninsula the first blossom suffered very heavily from damage by the mildew fungus.

Selangor

The inland foothill rubber areas were first inspected on the 20th April and at that time the foliage appeared to be in rather poor condition. Several counts in representative areas indicated that about 20 per cent. of the trees had obtained a new healthy foliage, some 40 per cent. were either bare of foliage or buds had just shot and 20 per cent. of the trees were still in the wintering stage with old brown leaf falling. The young leaf or flowers from the freshly-shot buds was in most cases mildly attacked by the mildew fungus, but while considerable fall of leaf and flowers from the lower shaded branches occurred the top foliage assisted by further bright periods survived the attack surprisingly well. Further north, in the districts of Kuala Kubu and Tanjong Malim, wintering had been earlier and more satisfactory so that 80 to 90 per cent. of the trees had obtained their new healthy foliage before the break in the weather and only the remaining trees late refoliating had suffered a mild attack.

As last year the wintering on the peat and coastal clay soils did not seem to be so severe as that of the inland districts and it was common to see old green leaves and young new green leaf in one area at the same time and often on the same tree. However, the trees or parts of trees wintering late had suffered a mild attack and slight leaf fall by the end of the season. The foliage being normally heavy in most of these coastal areas, appears to be more than adequate to the needs of the tree and there seems no need for sulphur dusting such areas, a need which may however arise on some of the hard soils of coastal hilly areas.

Throughout April the bright sunny weather and occasional heavy showers ensured a good recovery of affected trees so that a very satisfactory foliage has now been obtained.

Perak

Southern areas of the State, after a relatively dry November-December period, medium dry January and February, appeared to have wintered satisfactorily and refoliation had been well advanced by the middle of March. Inland between Tanjong Malim and Ipoh the foliage had remained free of mildew disease and an exceptionally heavy, deep green canopy was recorded from most districts. The bright sunshine and rain of late March-April had induced a second growth flush which had been attacked by insects and leaf spot fungi resulting in many false reports of leaf mildew. In the Telok Anson district the peat flats had experienced a more mixed wintering, but late wintering trees after a very mild attack of Oidium had made good recovery and now show a very heavy canopy of foliage. In the south Perak districts the healthy scent of the Hevea flowers was very noticeable.

On some of the flat areas near Ipoh some late wintering trees were observed which were attacked by leaf mildew, and had suffered considerable leaf fall from their middle and lower branches. This again would probably be due to an abnormal wintering in August last year. In northern Perak conditions of wintering and refoliation were somewhat better and by the time the dry period ended in mid-March about 90 per cent. of the trees had obtained an excellent healthy new foliage. A few exceptions to this general observation were found near Taiping and Trong, where the local influence of nearby hills had caused local rains to interfere with the refoliation of the trees under conditions more favourable to mildew attack. Even so, the incidence of mildew in these areas was not regarded as being other than very mild. The coastal areas in the Sitiawan district had a rather mixed wintering with corresponding desultory refoliation so that the late wintering trees had suffered a slight attack of leaf mildew. Areas closer to the sea however had suffered less severely and had obtained an extremely good foliage at the time of inspection.

In the coastal districts of Sitiawan and Bagan Serai attacks by mites and Hevea thrips were recorded on young trees and the second shoot growth of older trees.

Province Wellesley

This State had enjoyed a very dry wintering period and the flat lands had completely refoliated by the end of March when first inspected, without any noticeable attack of mildew. On the more undulating hinterland a mild attack took place in early April on late wintering trees. On the whole there is little to report on the wintering and refoliation of this district which appear to have

followed the normal course. Only one estate reported the occurrence of mildew.

During the second inspection some thrip damage to second flush leaves was noted.

KEDAH

In the districts north of Sungei Patani a normal wintering and refoliation had taken place. A comparatively dry November-December period followed by a long uninterrupted dry period in January and February enabled the wintering to take place quickly followed by a quick refoliation before the break in the weather in March. The inland districts south of Sungei Patani were progressively later as the southern boundary was approached, and a mild attack of mildew on late-wintering trees had occurred but the amount of leaf fall was negligible. The flowers however were heavily attacked and first seed harvest is likely to be very poor.

The foliage of rubber trees throughout the State is considerably better than that obtained last year when a break in the January-February dry period severely retarded wintering.

PAHANG

Though visited rather later in the season the western districts of this State appeared to have had a late wintering generally but the subsequent weather, hot and dry with occasional heavy storms, had brought on a very healthy foliage in the older rubber. Younger areas seemed to have been considerably troubled by mite and spider damage.

On only one estate was the leaf mildew disease recorded. The inflorescences of many trees examined showed that they had been heavily mildewed and few seed had set.

Summary

The North East monsoon period which normally brings heavy rain throughout the Peninsula during the months of November and December failed to do so at the end of 1938. In consequence an early wintering was to be expected. However, January, 1939, proved rather more wet than usual especially in the central and southern States and thus caused a two to three weeks' delay in wintering. Fortunately, February was an ideal fine dry month over the whole country and a severe wintering was induced.

In the north the rubber had almost completely refoliated before any serious dull weather occurred and thus practically escaped attack by the mildew fungus. In the central districts and areas

at the foot of hills of greater altitude, owing to local climatic conditions the wintering had been delayed sufficiently to favour a mild incidence of disease in the late wintering trees. Although little serious leaf-fall ensued, first blossom appears to have been very seriously affected.

Further south, though later, the refoliation proceeded in bright weather and occasional heavy showers without any serious loss by disease and in general the foliage is well up to normal and in many areas rather better than in previous years.

Sulphur-dusting programmes in various parts of the country were either abandoned as unnecessary or curtailed so that only two or three rounds of dusting were actually carried out. The frequent heavy afternoon showers would considerably reduce the effect of the sulphur dust applied the same morning.

The sudden appearance of the disease within 48 hours of the onset of dull weather adds further support to the theory that the fungus hibernates in the buds of the trees and as these open the hibernating mycelium is able to take advantage of the advent of dull cool humid weather and produces an early crop of conidia which are rapidly broadcast.

Kuala Lumpur

18th May, 1939

THE DEVELOPMENT OF JUNGLE RESERVE LAND FOR PLANTING WITH RUBBER*

BY

H. J. PAGE

The development of new areas of reserve land for planting in 1939-40, which is permitted under the new agreement for 1939-43, makes it desirable to summarise available information on this subject. This has been done in the following recommendations.

Selection of Areas

The Rubber Research Institute is unable to undertake the inspection of jungle land with a view to the selection, from the reserve areas owned by estates, of those sections which may be best suited for cultivation with rubber. Such prospecting work is outside the scope of the normal work of the Institute and could be undertaken only at the expense of that work. The Institute is willing to assist in the matter of advice on the preparation of soil profile pits, and the examination of soil samples, but cannot give personal assistance in the work of prospecting and preliminary examination of reserve jungle areas.

Questions concerning the suitability of sites, and their value for planting, in relation to drainage, topography, and similar considerations, are regarded as local problems which must be investigated by the estate staffs, whose knowledge of local conditions should enable them to deal adequately with such questions.

Preparation for Planting

(a) *Felling.*—All trees should be felled at about three feet from the ground. On hilly land the timber should be disposed along contours as much as possible. If a preliminary rough lining for terraces can be carried out before felling the correct disposal of timber may be made more easily.

(b) *Burning.*—A light burn should follow felling as soon as sufficient drying has occurred to ensure that most of the light brushwood, undergrowth, branches and small trees will be destroyed. This can usually be done three weeks after felling. Complete

* This paper is substantially the same as one read at the 14th Annual Conference of The Incorporated Society of Planters held at Penang from the 23rd to 25th September, 1938.

burning of all timber is not recommended, except where the jungle stand is known by experience in neighbouring areas to be heavily infected with root disease, when a more drastic method of burning, clearing and stumping may be advisable.

(c) *Clearing and Stumping.*—Burning is followed by clearing of timber along contour belts or along the planting rows, depending on topography, and timber is slewed between the cleared belts. On undulating or steep land, timber should be slewed as much as possible along contours in order to check erosion. To prevent rolling of long, heavy logs, these should be held in place by smaller timber and, where necessary, by hardwood stakes driven firmly into the ground.

Stumping is confined to strips six to eight feet in width along the cleared planting rows or contours. Stumps, up to eight inches in diameter at three feet from ground level, should be removed and piled between the rows. Felled timber, up to 15 inches in diameter, should be cut and slewed clear of rows.

(d) *Lining.*—Intervals between contours or rows will depend on the type of land and on the choice of planting material. If buddings of the best proved clones are to be used the intervals should be chosen so as to give an initial planting density of about 150 to 180 points per acre. If clonal seed is used intervals should be reduced to give an initial density of 220 to 250 points per acre. Suggested spacings are indicated in the table given below:—

Table of suggested Planting Distances in feet;

(Corresponding number of plants per acre shown in brackets.)

Type of Soil	Type of Material and System of Planting			
	(a) Contour Terraces		(b) Flat Land—Square Planting	
	Clonal Seedlings	Proved Clones	Clonal Seedlings	Proved Clones
Good	20 x 9 (242)	20 x 15 (145)	18 x 10 (242)	20 x 15 (145)
Poor	20 x 8 (272)	20 x 12 (181) or 22 x 11 (180)	18 x 9 (269)	18 x 14 (172)

(e) *Terracing and Bunding.*—On hilly land, contour terraces are recommended. These should be of a minimum width of four feet and the angle of slope will depend on the type and texture of the soil. In very light sandy areas it is necessary to cut terraces with a steeper inward slope than on the heavier clays, or gravelly, hill soils, in order to prevent excessive erosion. Halfway along each interval between points, or each alternate interval, two-feet-wide earth "stops" should be left uncut to check lateral flow of excess water along terraces.

On undulating land, earth bunds following the contours may be all that is required to check wash. These bunds should be not more than two feet high, and the number per acre will again depend on the steepness of slope and texture of the soil.

(f) *Holing.*—Holing may be commenced as soon as the work of clearing is sufficiently advanced, and it is important that filling should be completed at least one month before planting is intended, in order to give the soil sufficient time in which to settle. The size of the planting hole will depend upon the nature of the planting material to be used, as detailed below. When digging the hole, place the top-soil on one side and the remainder of the soil on the other side. There is no necessity to leave the holes open for any longer than is necessary to check the actual work of digging them, so that soil may be rapidly replaced and firmly pressed down in the holes in the same order as it was before being disturbed. Before planting, any subsidence in the holes can be made good by filling the depressions with good top-soil and the final level of the soil should be two to three inches above the general level beyond the hole so that further subsidence, with its attendant dangers, may be allowed for prior to planting.

Size of Holes for different Types of Planting Material

(i) *Basket Plants and Germinated Seed at Stake*

Dig an 18-inch-cube hole and loosen the subsoil at the bottom of the hole. Replace the bulk of the subsoil and fill the remainder of the hole, the uppermost six to nine inches, with good top-soil.

(ii) *Stumps*

The soil in the planting hole should be thoroughly disturbed to a depth which will be six inches below the cut end of the tap root when in its final position after planting.

(a) Seedling stumps, 18-inches tap root: 18-inch-cube hole, forked at the bottom to an additional depth of six inches.

(b) Budded stumps, two feet six inches tap root: two-foot-cube hole, tapered another six inches to two feet six inches deep, and the sub-soil in bottom loosened to a further depth of six inches.

(c) Stumped buddings, according to size, may require a three-foot-cube hole which should further be forked at the bottom. With stumped buddings, filling and planting are best done in one operation so that the strong lateral roots may be correctly disposed and the soil well tamped around them. Any subsidence of soil in the hole after planting should be made good by filling the depressions with further top-soil.

Planting Material

There is no single type of planting material which can be said to be the best for all conditions. The principal improved material available for large-scale planting consists of buddings of the best proved clones and seedlings of the best, approved families. The present views of the Institute on the relative value of buddings and clonal seedlings have been set out in another paper read at this Conference (See page 79).

If buddings are to be used we recommend planting four germinated seeds per hole at the corners of a one-foot square, to be budded when they have reached a minimum diameter of 1¼ inches at four inches from the ground. Clonal seed, from mixed budded areas, is preferred to unselected seed. For supplying, basket plants should be used. Budded stumps are not recommended except on rich coastal soils, and then only when planting can be carried out during the most favourable planting period.

Clonal seed of approved high-yielding families is usually expensive, and planting one basket plant per point is, in consequence, the usual method adopted. Provision should be made for supplying up to 20 per cent. of points.

It should be remembered that after a light burn, with much timber left on the land, and with a good growth of covers, there is more harbourage for ground vermin, notably rats. A sharp look-out must be kept for damage by these pests, and steps taken to protect the young plants.

Covers

(a) *Establishment of Covers*

The question of the best type of cover to encourage is still in debate. Experiments have not been in progress sufficiently long

and therefore from the results obtained, definite conclusions are not possible at present.

From the evidence available, on economical and general grounds, it is recommended that the best types of natural covers should be used, together with planted legumes. Creepers, *Pueraria javanica* and *Centrosema pubescens*, should be planted in drills along the edges of the planting rows or terraces, with the object of encouraging them to spread between the rows of rubber plants. Wherever open patches occur amongst the lying timber, leguminous bushes should be planted, using any of the leguminous shrubs such as *Tephrosia candida, Tephrosia Vogelli, Tephrosia maxima, Crotalaria anagyroides* and *Crotalaria usaramoensis*. Inoculation and manuring of these covers may be necessary.

Recent experience has shown that *Desmodium ovalifolium* may be a useful cover for establishing along bunds, paths, and terrace edges. It is however, very susceptible to "root-knot" disease caused by eel worms, which may spread to other covers which are not, as a rule, seriously affected. We do not therefore advise the use of Desmodium as a substitute for the creeping or bush legumes mentioned above, in areas where the "root-knot" disease is prevalent.

(b) *Weeding and Control*

The terraces and planting rows should be kept clean-weeded for a minimum width of four feet. "Slicing," in order to sever cover-plant roots and so reduce the danger of competition with the young rubber plants, may be advantageous during the first six to twelve months after planting. Bush covers must also be controlled to prevent any overshading of the young rubber plants, by side pruning and also by slashing at four feet from the ground.

Prunings from cover plants should be placed around the rubber plants as a surface mulch in order to conserve soil moisture, to keep the soil cool, and to discourage the growth of soft weeds.

As the indigenous covers develop, further selection and eradication of the least desirable types will be possible.

Manuring

It is not likely that manuring in soil from virgin jungle will be necessary in the early stages, but indications of mineral deficiencies may become evident during the early life of the plants and specific manuring will become desirable. On the other hand, certain soils are known to be inherently deficient in some elements of plant food and where such knowledge is available suitable manuring should be given to young plants from the beginning.

FURTHER NOTES ON BURNING, COVERS AND MANURING*

BY

C. G. AKHURST

In the general recommendations for the development of jungle reserve land for new planting with rubber, (see page 68) the main departures from earlier customs and practices are concerned with burning, covers, and manuring, and these operations are discussed in more detail in the following paragraphs.

Burning

In most tropical lands burning has been invariably used for removing jungle debris and trash prior to planting agricultural crops, and where annual or close-growing crops are concerned there is probably no better alternative procedure.

Where rubber trees (or similar long-term crops, planted with comparatively wide spacing) are to be grown, other aspects of the subject need to be considered.

Complete clean-clearing of the soil is not important at the start because the young plants, for several years, use only a small proportion of the land to which they are allotted; a light burn and the retention of as much forest trash as possible consistent with normal supervision of, and movement through, the area, carry several advantages over normal burning, which are listed below.

Soil Protection.—Malayan rainfall is often very intensive and full protection against soil erosion is required on newly felled land as quickly as possible. Similarly, unduly prolonged exposure of a bare soil to the sun is bad. Both these effects are minimised by the retention of timber and debris, and rapid establishment of covers.

Organic Matter.—Most of the unburned plant material, sooner or later, forms organic matter or humic material in the soil and, in spite of the slow rate of decomposition of those plant portions which have low nitrogen-contents, the comparatively low humus-status of Malayan soils in general makes it extremely desirable to retain this plant material.

* This paper is substantially the same as one read at the Fourteenth Annual Conference of The Incorporated Society of Planters at Penang from the 23rd to 25th September, 1938.

Soil Burning.—Whilst the dangers from soil burning are liable to be rather over-emphasized, the light burn or "scorch" reduces these to a minimum. On peat soils there is a great danger of doing permanent harm to the soil by heavy burning, and for these soils only a light burn should be employed when clearing jungle.

Loss of Minerals and Nitrogen.—Much of the nitrogen content of the plant-debris is lost during burning, and in heavy burns considerable loss of the more volatile mineral plant foods may occur *e.g,* phosphate and potash. In any case, the ash material containing immediately available plant-foods, which is returned to the soil, tends to be concentrated in spots or patches, so that the newly planted rubber may not reach it for several years, by which time part of the plant foods may be immobilised in the soil or leached out.

Whilst no figures can be quoted which give the quantities of plant foods contained in jungle trees, the following figures taken from an analysis of a single rubber tree are of considerable interest. The data quoted below are taken from the investigation by Dr. A. W. J. Dyck reported on pages 6 to 13 of this Journal.

The total weight of the tree was about 5 tons, of which one-third was water, and the leaves alone amounted to over 3 cwt. The analysis of leaves and stalks together gave the following figures:

Nitrogen	4.2 lb.
Phosphoric acid ($P_2 O_5$)	0.6 „
Potash ($K_2 O$)	1.9 „
Calcium oxide	3.3 „
Magnesium oxide	1.2 „

Weights of different parts of the tree:

Leaves and stalks	423 lb.
Twigs	650 „
Small and side branches	1,867 „
Main branches	3,657 „
Main stem	3,338 „
Roots	1,764 „
Total ...	11,699 lb.

Jungle trees and debris will not necessarily have a similar composition, but their plant food contents will be of a similar order, and thus nitrogen losses through burning will be heavy. An uneven distribution in the soil of the large amount of minerals

in the ash is obviously undesirable, and is least likely under conditions of light burns.

Covers

The value of covers to the soil, under Malayan conditions, lies in many directions but for the matters under discussion, their effects on young rubber plants during the first year or two of growth will be considered.

In a new clearing, whilst an excessively heavy and uncontrolled growth will check the rubber, a good growth of controlled covers is essential as quickly as possible in order to help shade the soil and prevent soil wash. Further, the more rapidly covers are established, the sooner will be available plant material for surface soil mulching.

Leguminous covers, if planted in new clearings, will establish fairly quickly, in three to six months, particularly if aided by phosphatic manures, but by combining them with 'natural' covers an even quicker covering of the soil is achieved. By using a 'light' burn far fewer seeds and young forest plants are destroyed, and the establishment of 'natural' covers is made easier and less dependent upon fortuitously borne seeds.

The retention of timber and jungle debris, provided it is not so dense as to *smother* any new plant growths, provides cool and shady spots which are particularly favourable to newly germinating seeds and spores, and in any new clearing, the first places where ferns appear are on the undersides of timber, along drain edges, etc.

The value of mulching to young rubber plants is considerable on all soils, but is greatest on the sandy loams, derived from granite or quartzite rocks, and also in the drier parts of the country.

Experimental planting areas which were planted in 1937 have demonstrated, where rainfall has been very unevenly distributed, that manuring and soil type have had little effect on the development of the rubber plants, but that soil moisture has been the limiting growth factor. This has been particularly noticeable in Central and South Johore districts.

Experiments have clearly shown that cover crop roots, by competing with the rubber for moisture, will severely retard the rubber plants, although this can be reduced by 'slicing'; the following figures indicate the benefits arising from mulching. The experiment was laid down in a flat, heavy loam soil, and mulching was not commenced until seven months after planting when the rubber and the cover were well established.

Heights in inches

	May	June	July	Aug.	Sept.
Mulched ...	73.2	—	97.6	106.4	120.7
Not mulched ...	75.7	—	100.0	104.7	118.3
Rainfall (inches) ...	6.5	2.4	2.5	5.5	—

Height Increments in inches

	May/July	July/Aug.	Aug./Sept.
Mulched ...	24.4	8.8	14.3
Not mulched ...	24.3	4.7	13.6

The effect of the two months (June and July) on the growth of even these well developed and vigorous plants (average monthly growth 10 to 11 inches) is clearly shown, and of particular interest is the value of the mulching (which was first done in May) as shown by the very nearly doubled growth rate during July to August of the mulched over the un-mulched plots.

The present recommendations, therefore, of using a light burn or scorch, retaining as much timber and debris as conveniently possible and using a mixed system of leguminous covers with "natural" covers have the following objects in view:—

(1) to reduce soil erosion losses by utilising timber and by rapidly producing a cover;

(2) to encourage a quick regeneration of natural covers which will help in achieving (1) and also shade the soil and provide mulching material;

(3) by achieving (1) and (2) and maintaining soil fertility and soil moisture conditions, to produce the best possible growth in the rubber plants.

The main disadvantages lie in the tendency for the masses of debris to encourage rats and other pests, against which countermeasures may be an expensive item, and in the difficulty of carrying out adequate root disease work, after planting, where the amount of lying timber is considerable.

The actual growth of rubber trees under different types of covers and methods of clearing jungle is being studied by the Institute on experimental planting areas, and an obviously important matter is the relative cost of the different methods of preparing the jungle land and of the subsequent weeding and upkeep work. The experiments have not progressed sufficiently yet to allow any definite conclusions to be drawn.

Regarding costs, it appears that between "normal" burning and "light" burning there is likely to be very little difference, but if clearing without any preliminary burning is attempted, the cost is very nearly doubled.

Weeding of Covers

The weeding practices on rubber plantations in Indo-China and in Dutch East Indies differ from those of Malaya for the first year after planting, in that the land is generally kept clean-weeded for that period, the object being to reduce competition.

This practice is not endorsed; the reduction of competition can be achieved by maintaining a cover under suitable weeding methods.

Competition from a cover crop has the greatest retarding effect on rubber plants during their first few years of growth while they are endeavouring to establish their root systems in the soil, and during those years everything must be done to reduce that competition.

The ideal arrangement would be to weed the cover in constantly widening circles or strips so that the cover crop roots never interfere with the rubber roots.

Whilst this is not attainable in practice, a satisfactory compromise can be reached by commencing with clear circles around plants which are widened up to eight feet diameter and then formed into clear strips of the same width at two years from planting. At the same time soil mulching on the bare soil and, if necessary, "slicing" along the edges of the cover will prevent undue drying of the uncovered soil and ensure that no underground root competition takes place.

It must be emphasized that these operations are of most importance during the first few *months* of the rubber plant's life, and after a year or two, the rubber tree's root system should be developed well enough to stand a fair amount of competition and the foliage, provided that the planting has been sufficiently close and that the clone used branches fairly quickly, will be closing in and helping to control the covers and reduce the competitive effects.

Manuring

A large number of manuring experiments on virgin jungle land of different soil types have been commenced in 1937 by the Soils Division, and these indicate that little or no manuring of the rubber plants is required during the first six months after planting.

On certain soils, particularly the loams and clay-loams derived from quartzite rocks, phosphate manuring produces quite definite height increases (10 per cent), but as a general rule manuring during the first twelve months can be omitted.

RECOMMENDATIONS ON THE CHOICE OF PLANTING MATERIAL

CLONES AND CLONAL SEEDLINGS*

BY

C. E. T. MANN

General Considerations

During the past two years the relative merits of buddings and clonal seedlings (seedling families derived from good parent clones) for use in large-scale planting, on replanted and on new areas, have been the subject of much discussion.

It may be stated at once that we shall have no preference for buddings over "clonal" seedling families or *vice versa* when it has been demonstrated, by reliable comparative tests, that the seedling families are equivalent in value, both in production and in secondary characters, with buddings of the best proved clones. When this has been established and a satisfactory method has been developed for producing with certainty large quantities of seed of the same parentage as the small families which have been tested, then commercial planting of the best families of clonal seedlings may be undertaken with safety.

For the present, the *legitimate* seedling families which have been proved to be equivalent in yield and in other important characters to buddings of the best proved clones, such as Tjirandji 1, Prang Besar 86 and Pilmoor B. 84, are very limited in number. Until quite recently, no satisfactory method of producing seeds of these valuable families on a sufficiently large scale to provide the large quantities of seed required for commercial planting had been demonstrated. We still await proof of the relative value of clonal seedlings and buddings of the best proved clones planted and treated under strictly comparable conditions.

Thus, our present knowledge of the value of the best clonal seedling families in practice is about equivalent to our early knowledge of buddings some eight years ago, so that in general, the clonal seedlings available for commercial use must be regarded as unproved material.

The extensive planting of unproved material cannot be justified. We therefore strongly advise against the planting of clonal seedlings, in preference to buddings, on more than an experimental scale.

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* This paper is substantially the same as one read at the 14th Annual Conference of The Incorporated Society of Planters held at Penang from the 23rd to 25th September, 1938.

It is appreciated that there are many planters who still retain their prejudice against buddings and who will take the first opportunity to revert to the older practice of seedling planting.

It would be unwise to discourage completely the planting of promising clonal seedling families, for it is only by extensive trial under many and varied conditions that the relative value of such material can be assessed with certainty. *Nevertheless, we strongly advise even those who are prepared to risk the commercial planting of promising, but virtually unproved, material, that the area allotted to such planting be limited in the maximum to 20 per cent. of the area to be planted.*

In view of the keen general interest in the merits of clonal seed further salient facts, relating to the development and large-scale production of seedling families, are recapitulated here.

By means of carefully controlled artificial pollination (by hand) limited numbers of very promising families of clonal seedlings have been obtained and tapping tests, covering several years, have shown that the best of these seedling families may give yields equivalent to those of the best clones. The demonstration of this important fact has been given a great deal of prominence, and as a result a strong impression has been created in many quarters that the time has now arrived to abandon the planting of buddings in favour of clonal seedlings. This impression is unfortunate and, in our opinion, dangerous, for it is ill-founded. It is a great pity that other essential facts relating to the development of the best seedling families have not, in general, been given sufficient emphasis. It is therefore emphasised now that *only a few of the original families of clonal seedlings, obtained by carefully controlled hand-pollination, have been shown to be equivalent in productive capacity with buddings of the best proved clones.* The most promising families of legitimate seedlings are not more than ten years old and our knowledge of their performance is limited, in most cases, to about five years' tapping experience; whilst for the best of the proved clones over ten years' experience of tapping has been obtained, supplemented, for most clones, by further tapping experience on large numbers of younger trees in subsequent plantings.

Working on the assumption that it would prove impracticable to produce sufficient quantities of seed by means of artificial (hand) pollination to provide materials for commercial planting, various means have been tried in order to raise large quantities of seed of known, or at least partially known, parentage in the hope that the success of the small-scale investigation could be repeated on a large scale. The principal method employed—the establishment of isolated gardens planted with a limited number of carefully

selected parent clones—has given promise of success. It remains to be proved, however, to what extent the mass-production of seed from isolated gardens will give results equivalent to those from small families of seeds obtained by carefully controlled crossing between pairs of selected parents.

An example will serve to illustrate the wide variation in the composition of the seedling progeny which may be obtained from a typical isolated garden. In such a garden planted with ten selected parent clones the possibility exists that 100 different families of seedlings (including reciprocals and selfs) may be produced. The actual number of these families which have been raised and studied by means of artificial pollination represents, as a rule, a very small proportion of the total. The proportion of the total seed crop which consists of the tested families will be quite unknown and therefore it is essential that the value of the progeny of such a garden be tested and proved in much the same manner, and for as long a period, as a promising new clone requires to be tested before planting on a large commercial scale can be justly advised.

It may certainly be assumed that the seed progeny of a garden planted with well-known parent clones will be greatly superior to ordinary unselected seed, but it cannot be assumed that such material will be equivalent in value to the buddings of the best proved clones. Preliminary tapping tests on material from isolated gardens have given the most encouraging results, but we still await final proof of their true commercial value.

It has been stated above that the system of planting isolated seed gardens was based, in part at least, on the assumption that artificial hand-pollination for the production of seed in commercial quantities would prove impracticable. Recent attempts to produce large quantities of seed by hand-pollination, which have been made principally in Java, have met with considerable success. Already a number of enterprising estates have successfully trained large gangs of coolies in the simple, though tedious, technique of hand-pollination and during the current season large areas will be planted with legitimate seeds of the best of the high-yielding families of seedlings which have been obtained in the earliest work on crosses.

A number of valuable high-yielding seedling families have now been under test for several years so that on estates where mature buddings of the parent clones of these families are available hand-pollinations may be made in large numbers with the certainty that seedlings of the same value as those originally tested will be obtained.

Reference to the *Annual Report* of the Rubber Research Institute for 1937 illustrates clearly that the same cross, for example B. 84 × A. 44, has given seedlings of the same order of merit during three successive seasons (p. 112, Table XIV).

Only legitimate seedlings, that is to say seedlings obtained by controlled crossing by hand, of the best of the legitimate families which have been already "proved" by tapping tests extending over several years, can at present be regarded as equivalent in value to buddings of the best proved clones.

All other clonal seedlings must be regarded as unproved material and claims that such seedlings are of equal value with buddings of the best clones have yet to be substantiated.

The general recommendations on choice of Hevea planting material which are now given below are based on the foregoing considerations.

Buddings

It is impossible to select from the large number of proved clones available for large-scale commercial planting one clone which may be regarded as the "best" for all situations but it is now possible to make a broad distinction between clones which have given promise of excellent performance under a wide range of conditions and those which appear to be particularly adapted to certain specified conditions.

For convenience, clones are classified in two Groups A and B, but it must not be assumed that clones of Group B are necessarily inferior to those of Group A. In fact, it is quite likely that clones of Group B, when grown under conditions more favourable to themselves than to those of Group A, may prove superior to them.

A. Clones:—Tjirandji 1, Tjirandji 16, Prang Besar 86, Pilmoor B.84 and Prang Besar 25.

B. Clones: –Glenshiel 1, Pilmoor D.65, Prang Besar 186, Sabrang 24, Avros 49, Lunderston N, and Bodjong Datar 5.

Full details of the yield records and other characteristics of the clones enumerated above have been published elsewhere but the principal characters and notes on the environmental conditions which appear best suited to these clones are given in brief below.

The Institute is always willing to give more detailed information and advice on questions of selection and allocation of clones for specific areas.

GROUP A

TJIRANDJI 1

On the basis of the original yield records of the first buddings of the clone, planted in 1920, and from the early records from

comparative tests on younger trees, clone Tjirandji 1 has proved to be the highest-yielding clone available for general commercial planting in Malaya. The clone is a vigorous grower under a wide range of conditions. Its principal defects are susceptibility to mechanical damage, very pronounced fall in yield during wintering and, during certain seasons, a tendency towards troublesome late flow of latex after tapping.

None of these secondary defects is in our view sufficiently serious, at least in Malaya, to detract greatly from the primary value of the clone as a very high producer.

Tjirandji 16

This clone is the same age as Tjirandji 1 and has also proved a very satisfactory clone under a wide range of conditions. Though less robust in growth than Tjirandji 1, clone Tjirandji 16 does well on all except the poorest soils. Resistance to mechanical damage is very good, and yields do not fall heavily in the wintering season. Early yields are about equal to those of Tjirandji 1 but the rate of increase in yield is less impressive.

Prang Besar 86

Established in June 1923, this clone appears to be one of the best all-round clones in the original Prang Besar collection. So far as we are aware the clone has developed no defects which merit special mention. Its habit of growth makes it satisfactory for all conditions; it does well on the rich alluvial clay soil in the coast districts and is satisfactory on the rather poor quartzite soils on hilly inland estates.

Pilmoor B. 84

Planted in November 1924, this clone probably possesses the most satisfactory vegetative characters of any of the older proved clones. In vigour of growth it is about equal to Tjirandji 1; bark characters are excellent and resistance to mechanical damage is entirely satisfactory. Growth, after the first year, is excellent on all types of soil and the clone may be generally recommended with confidence. Comparative tests carried out in Sumatra, Java and Malaya have shown that Pilmoor B. 84 is only slightly inferior in yield to Tjirandji 1 in the early years of tapping; the results of these independent tests are in striking agreement and it is interesting to record that clone B.84 is recommended as one of the first choice of clones for large-scale planting in all three countries.

Prang Besar 25

The original buddings of this clone, planted in April 1922, have a very satisfactory history. Although in the early years, up to the age of eight to nine years, the trees are liable to suffer from storm damage this weakness appears to be overcome with maturity. Young buddings have grown well in a variety of different situations and yields on good soil areas are outstanding. In one large scale tapping experiment, on an area of 60 acres, during the first nine months of the fifth tapping year the actual crop harvested has been 1,090 pounds per acre, which is at the rate of 1,450 pounds per acre per annum. Bark renewal is exceptionally good in clone P.B. 25.

GROUP B

Glenshiel 1

Established in late 1921, Glenshiel 1 is a very satisfactory clone of medium vigour of growth. Very resistant to mechanical damage, the clone appears to be particularly well-suited to the alluvial soils of the coastal plains. Its only notable defect is that it may not maintain its good performance on the standard tapping system employed in all clone-testing experiments, namely alternate day tapping on half circumference. However, since we have records from certain areas which show that even when tapped every third day on half-circumference the yield of Glenshiel 1 may be equal to that of Tjirandji 1, we do not regard this weakness of the clone with any anxiety.

Pilmoor D. 65

This clone was planted in November 1924 and has been grown and tested with Pilmoor B.84. Until two years ago, D.65 gave slightly higher yields than B.84 but its vigour of growth and secondary characters, particularly bark renewal, are not so good as those of B.84. Early observations on young areas indicate that this clone may be one of the most suitable for the coast districts, but very little experience of the clone from tapping of young plantings is yet available.

Prang Besar 186

Established in April 1922, P.B. 186 was for many years considered to be the best clone of the Prang Besar collection. It was, however, realised from the outset that the bark characters of the clone were not entirely satisfactory. Experience of commercial tapping of young budded areas of P.B. 186 have recently shown

that defects in bark renewal, due to characteristic swellings near the dormant buds at the tapping level, may be more serious than we had originally anticipated. For general use therefore, we no longer recommend this clone, but on estates on which experience has already shown that the clone can be grown successfully, so that the pronounced irregularity of the trunks is not evident, then further planting of P.B. 186 on similar land may be advised. On unfavourable soils the defect described is generally more in evidence, so that we prefer to advise against the planting of this clone on areas where no previous experience of its development is available.

Sabrang 24

This clone has proved a satisfactory clone on coast land estates where it was first established in late 1921. Although the clone has not been widely used young buddings have also grown well on good inland areas, but on poorish sandy soils growth has been less satisfactory. Yields are satisfactory but not outstanding—the clone appears to be of about the same order of merit as Avros 49.

Avros 49

This clone is one of the oldest of the original Avros series, established in January 1919, and planted consistently in Sumatra until the present year; it has now been omitted from the most recent recommendations for the choice of planting material. A clone of medium productive ability, Avros 49 is regarded as a good sound clone with no notable defects. The tendency for lumping and premature coagulation of latex during the first year or two of tapping is troublesome in practice but cannot be regarded as a really serious defect.

Lunderston N

Although little known at present clone Lunderston N was established in March 1923 and regular tapping and recording of yields has been continued since 1928. Planted on a poor peat-clay soil on Lunderston Estate the actual yield performance of the trees did not compare favourably with that of other proved clones and therefore attracted little attention. Recent tapping results on younger buddings in comparative tests on different soils have shown that the yields of Lunderston N may prove outstandingly good under better conditions. The clone is of particular interest in view of the excellent results we have obtained from seedling families and from new clones derived from seedlings, of which Lunderston N is one of the parents.

Bodjong Datar 5

Clone B.D. 5 is one of the oldest proved clones known. Established in February 1918 tapping tests on the original buddings of the clone have been continued without a break since 1924 and yield records are available from 1926 up to the present time. A clone of slow development and slow rate of girth increase, the method of assessment of budded areas employed in Malaya, by which potential production was based on girth measurements, has done much to bring disfavour on B.D. 5. We still have great faith in the future of the older areas budded with this clone and where previous experience has shown growth to be satisfactory, generally on the best soil areas, further planting of the clone may still be recommended. Generally speaking, however, the slow early development and consequent low early yields, must be regarded as a rather serious disadvantage and younger clones of more robust growth and higher early production must be given preference.

Seedling Families

Our views on the planting of clonal seedlings have been given somewhat fully in the introduction to these recommendations. A list of promising legitimate families and illegitimate collections of clonal seedlings is given below.

Legitimate Seedling Families (Derived from proved clones by hand-pollination)

Tjirandji 1 × Tjirandji 16

The first crosses of this family were made at the Proefstation, West-Java. A group of some 400 trees of this family has been in test for nearly four years. Yield records are very good; the yields of the seedlings approach closely the yields of buddings of clone Tjirandji 1 at comparable age.

Tjirandji 1 × Tjirandji 1 (Selfed seedlings of Clone Tjirandji 1)

Although only a small group of seedlings of this origin are under test their yields are outstandingly good and compare favourably with those of the Tjirandji 1 and Tjirandji 16 crosses.

Pilmoor B. 84 × Pilmoor A. 44

Crosses of this family give high average yields but the value of the family is marred to a certain extent by the too frequent appearance of the undesirable bark and trunk characters of the parent A. 44.

Pilmoor A. 44 × Lunderston N

This family gives uniformly high average yields. A number of very promising new clones have been derived from seedlings of this cross.

Avros 157 × Avros 161

One of the highest-yielding families of the original series of crosses made by Heusser at the A.V.R.O.S. Experiment Station in 1921.

Avros 166 × Avros 161

This is another of the outstanding crosses of the original series made by the A.V.R.O.S. in Sumatra.

The above list includes the principal outstanding families of which the parent trees are available in Malaya and concerning which detailed records have already been published. Other very promising families have also been tested in this country and in Java, but either the parent trees are not available for use in Malaya or details of the origin of the parentage of the families have not been published.

Isolated Garden Seed (Seed from a number of parent clones by natural pollination)

In the absence of sufficient yield data and observations on the secondary characters of seedlings grown from isolated garden seed our estimate of the probable value of such material can only be based on our knowledge of the parent clones, and of their progeny from the results of preliminary breeding experiments.

Unfortunately, detailed information on their composition is not available for all gardens from which clonal seed is being offered for sale, so that it is impossible for us to make specific recommendations in regard to the choice of such material.

Illegitimate Seedlings (derived from proved clones by natural pollination)

When the identity of only one parent of a seedling, the mother tree which bears the seed, is known with certainty then such seed is defined as *illegitimate seed*. In this category we include seed from areas planted with more than two clones, duo-clone plantings where there is any risk whatever of pollen from outside sources reaching the seed-bearing trees, and seed from mixed plantings of clones.

Other supplies of Illegitimate Clonal Seed

There are a number of commercial plantings of buddings of the same clones that have been used as parents of very promising families. In some instances duo-clone plantings containing two good parent clones such as Pilmoor A.44 and B.84, are now producing considerable crops of seed. The chances are that seeds from the centres of such areas are likely to consist largely of true crosses of valuable clones. Such material is worth attention and planting on a small experimental scale can be recommended.

Further advice on the use of clonal seedlings and also advice on the probable value of the seed obtained from large commercial plantings on estates will be given on request. It may be stated, in order to encourage investigation of potential sources of supply of valuable seed, that there is yet little evidence to show that, for practical purposes, the mixed seed crop obtainable from the centres of large commercial areas which have been planted entirely with buddings of the best proved clones will be inferior to that obtainable from isolated seed gardens planted with a similar collection of clones.

The present paper deals exclusively with the choice of planting material for use in large-scale new plantings or replantings during the season 1938—1939.

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Edited by C. E. T. Mann on behalf of the Board of the Rubber Research Institute of Malaya.